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July 1980
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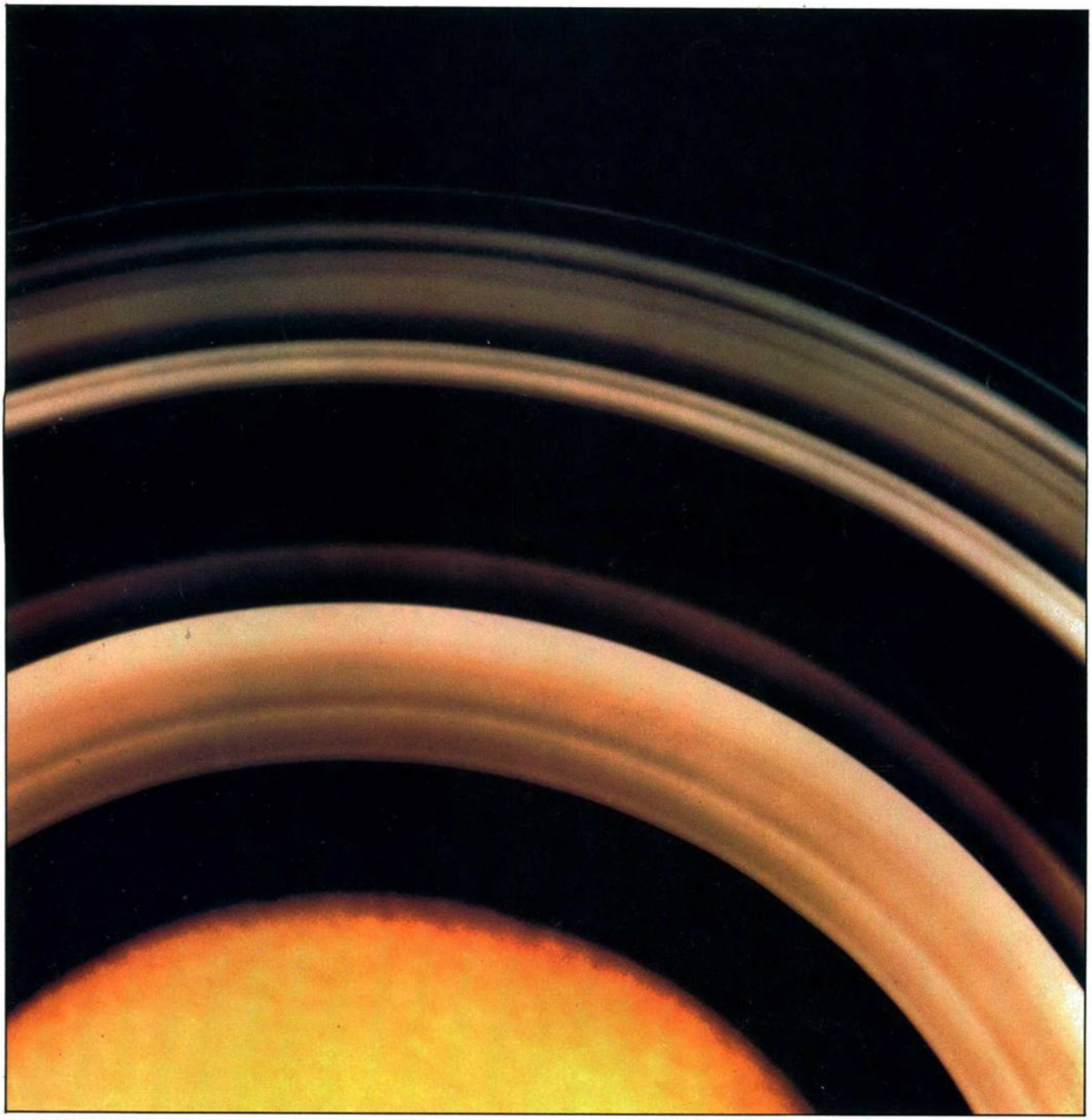
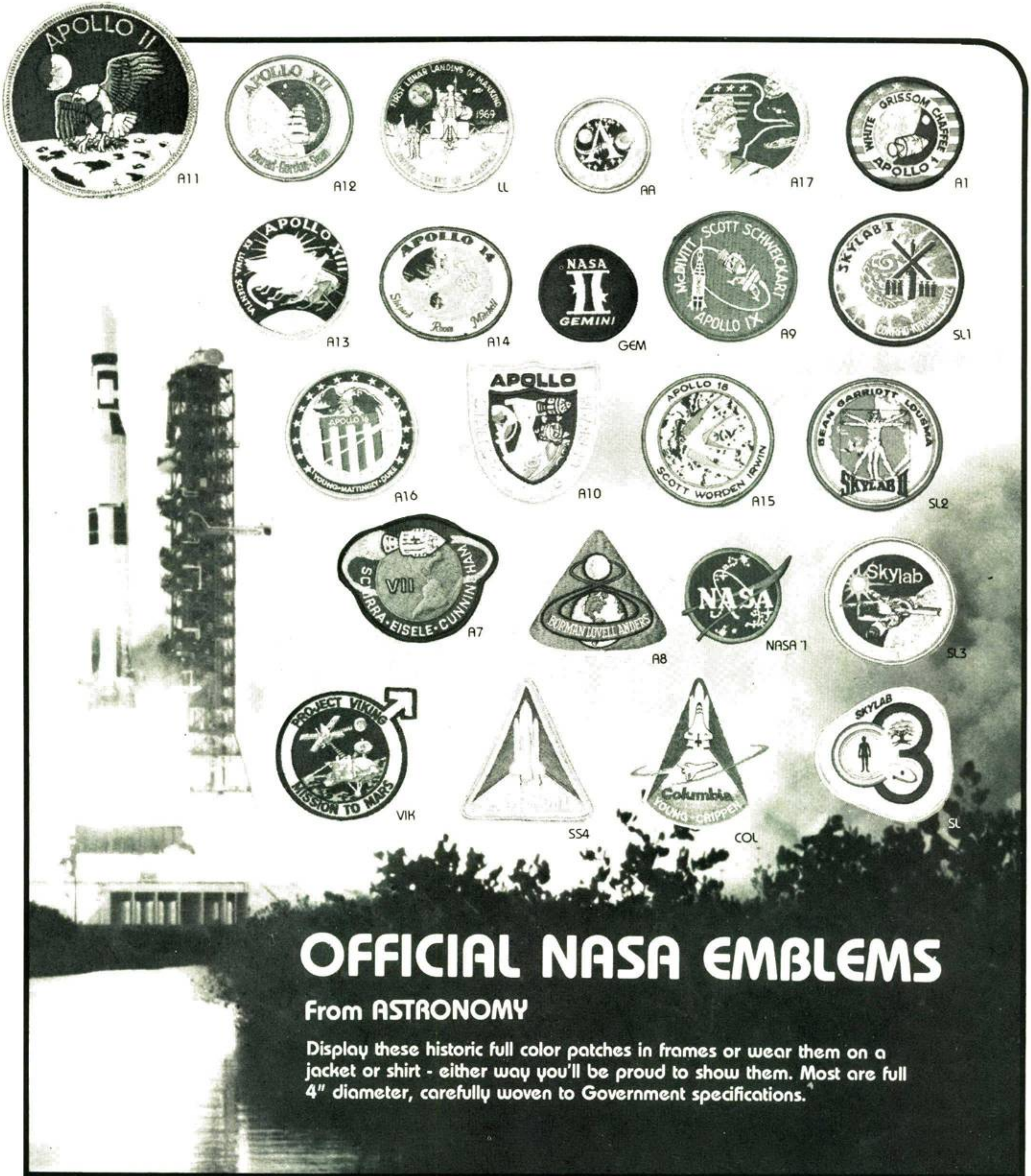
The Great Red Spot

The Puzzle of SS-433

Introducing the Summer Stars



Saturn's Rings



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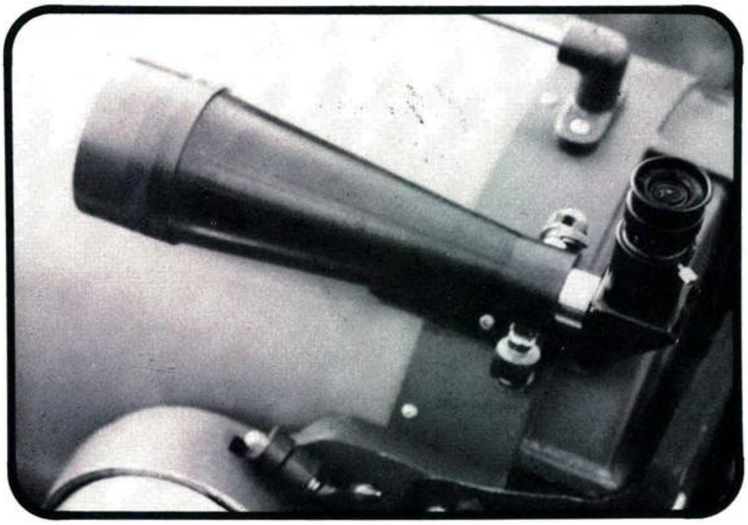

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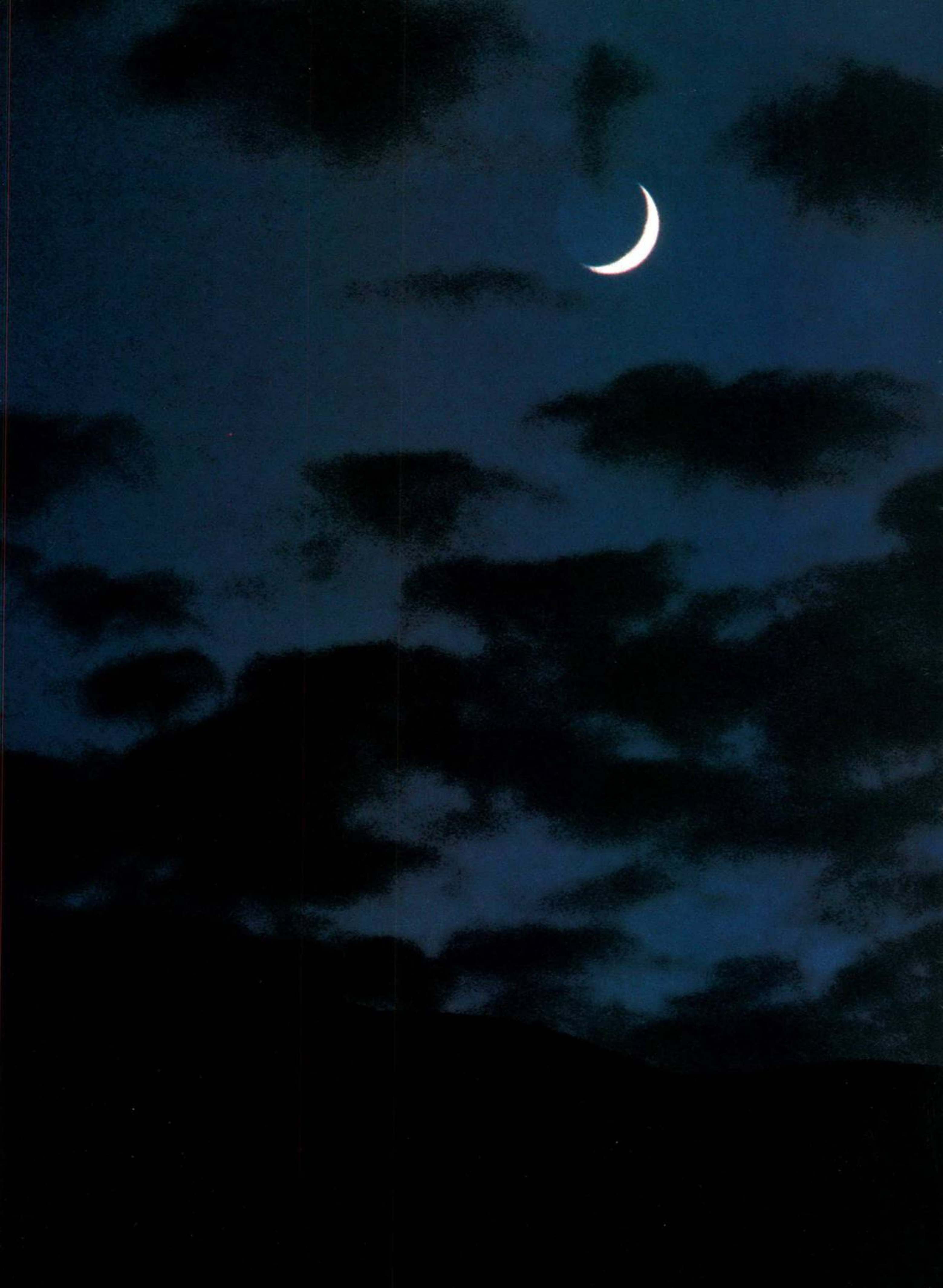

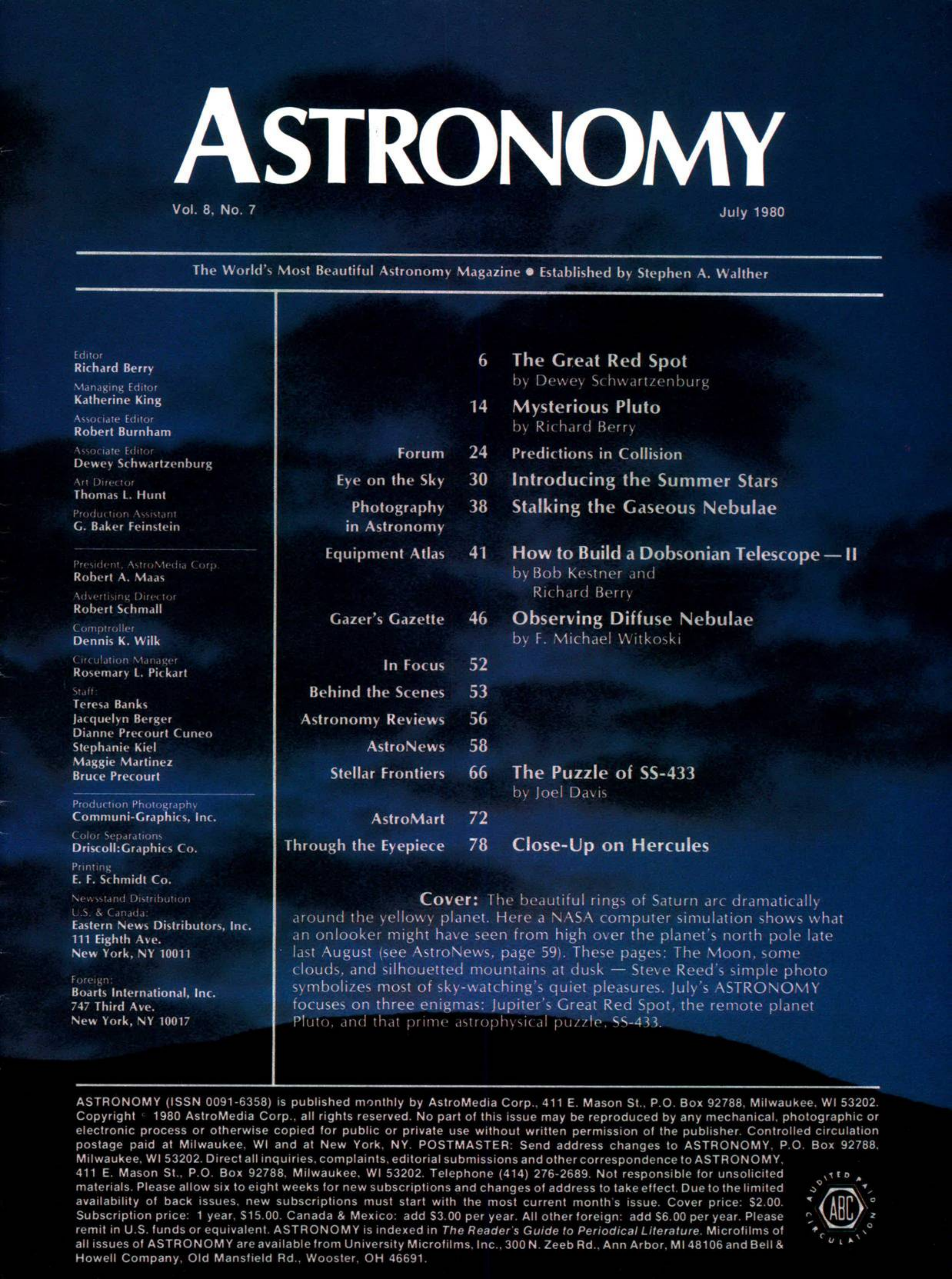

ASTRONOMY

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6 **The Great Red Spot**
by Dewey Schwartzenburg

14 **Mysterious Pluto**
by Richard Berry

Forum 24 **Predictions in Collision**

Eye on the Sky 30 **Introducing the Summer Stars**

Photography in Astronomy 38 **Stalking the Gaseous Nebulae**

Equipment Atlas 41 **How to Build a Dobsonian Telescope — II**
by Bob Kestner and Richard Berry

Gazer's Gazette 46 **Observing Diffuse Nebulae**
by F. Michael Witkoski

In Focus 52

Behind the Scenes 53

Astronomy Reviews 56

AstroNews 58

Stellar Frontiers 66 **The Puzzle of SS-433**
by Joel Davis

AstroMart 72

Through the Eyepiece 78 **Close-Up on Hercules**

Cover: The beautiful rings of Saturn arc dramatically around the yellowy planet. Here a NASA computer simulation shows what an onlooker might have seen from high over the planet's north pole late last August (see AstroNews, page 59). These pages: The Moon, some clouds, and silhouetted mountains at dusk — Steve Reed's simple photo symbolizes most of sky-watching's quiet pleasures. July's ASTRONOMY focuses on three enigmas: Jupiter's Great Red Spot, the remote planet Pluto, and that prime astrophysical puzzle, SS-433.

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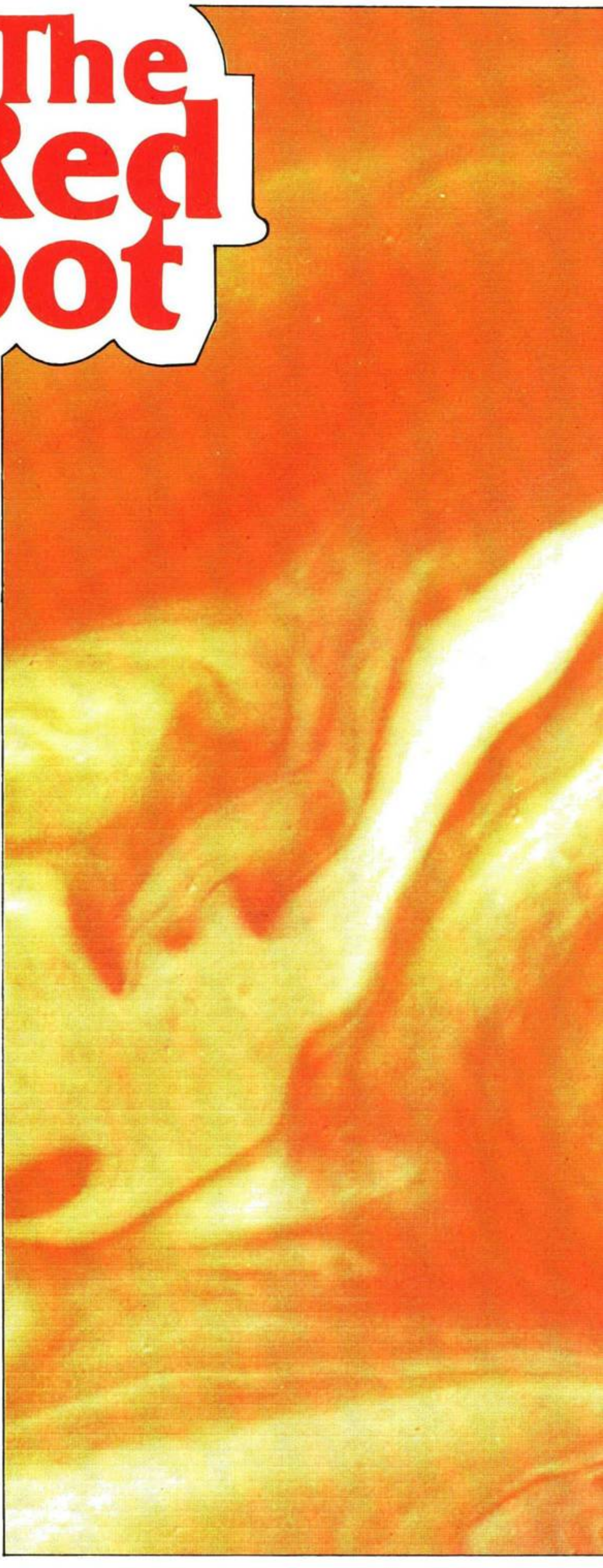
The Great Red Spot



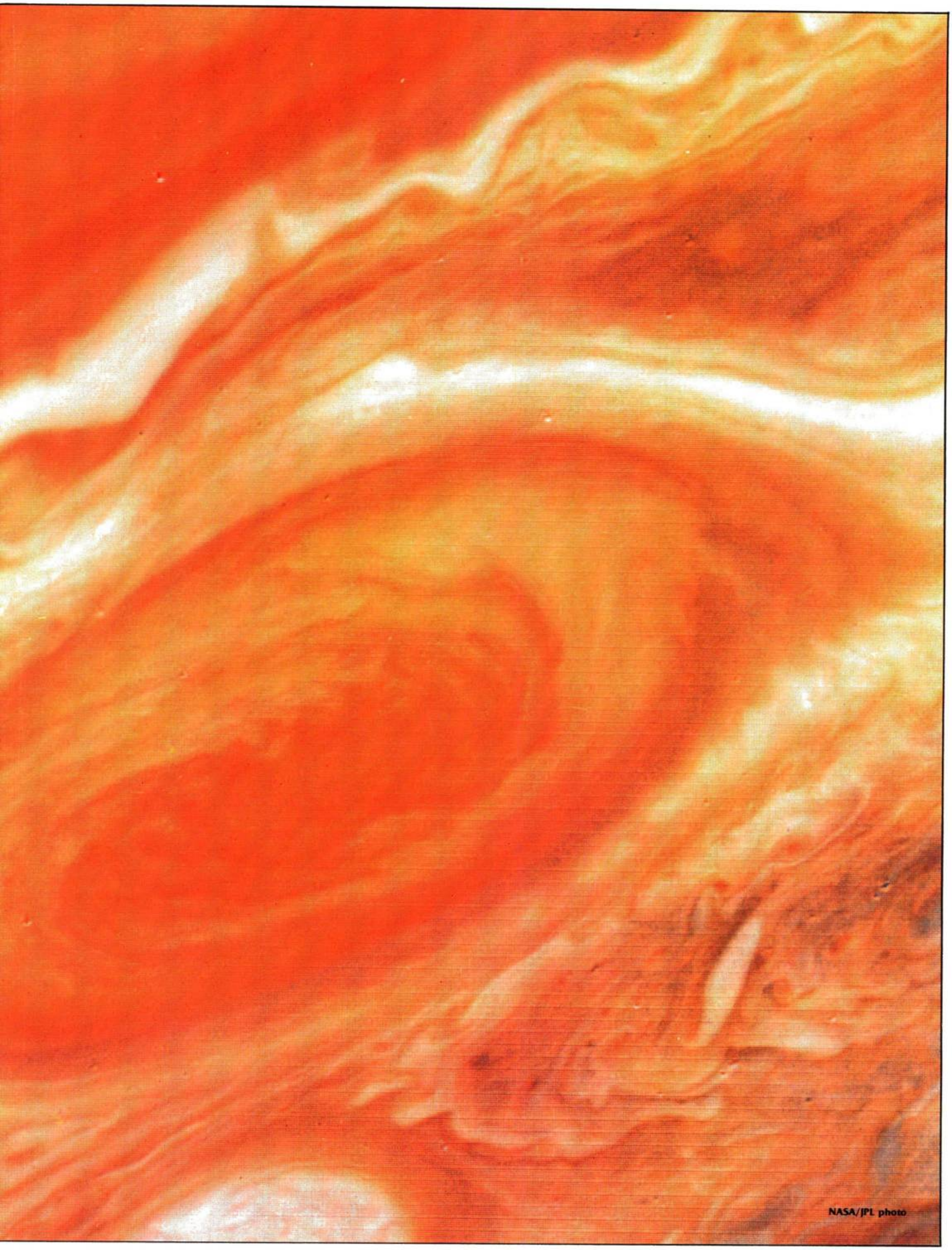
Huge and mysterious, sweeping around the giant gas planet like an all-seeing cyclopean eye, the Great Red Spot of Jupiter has fascinated mankind for generations. Discovered more than three centuries ago, the spot is as characteristic of Jupiter as rings are of its sister planet Saturn. If asked to describe Jupiter in a single sentence, most would offer something like, "A giant planet with bands and a red spot." But what *is* the Red Spot? Is it permanent or only temporary? What causes it? And why is it red?

Today, after three centuries of observation and four close flybys by robot spacecraft, we are much closer to being able to answer these questions. Yet a great deal of uncertainty and mystery remains. We are beginning to realize that the complete answers must involve an understanding of the structure, composition, and dynamics of a planet 1300 times larger (in volume) than our own Earth. That is a task which will challenge us and our ingenuity for decades to come.

The Great Red Spot was discovered in 1664 (see box on p. 13), and has been under virtually continuous observation for more than a hundred years. It is indeed a vast feature, though to our eyes it is dwarfed by the size of Jupiter. In fact, you could easily drop two whole planets the size of Earth into the Spot without touching its edges — the total area of the Red Spot is about the same as the surface area of our entire world.

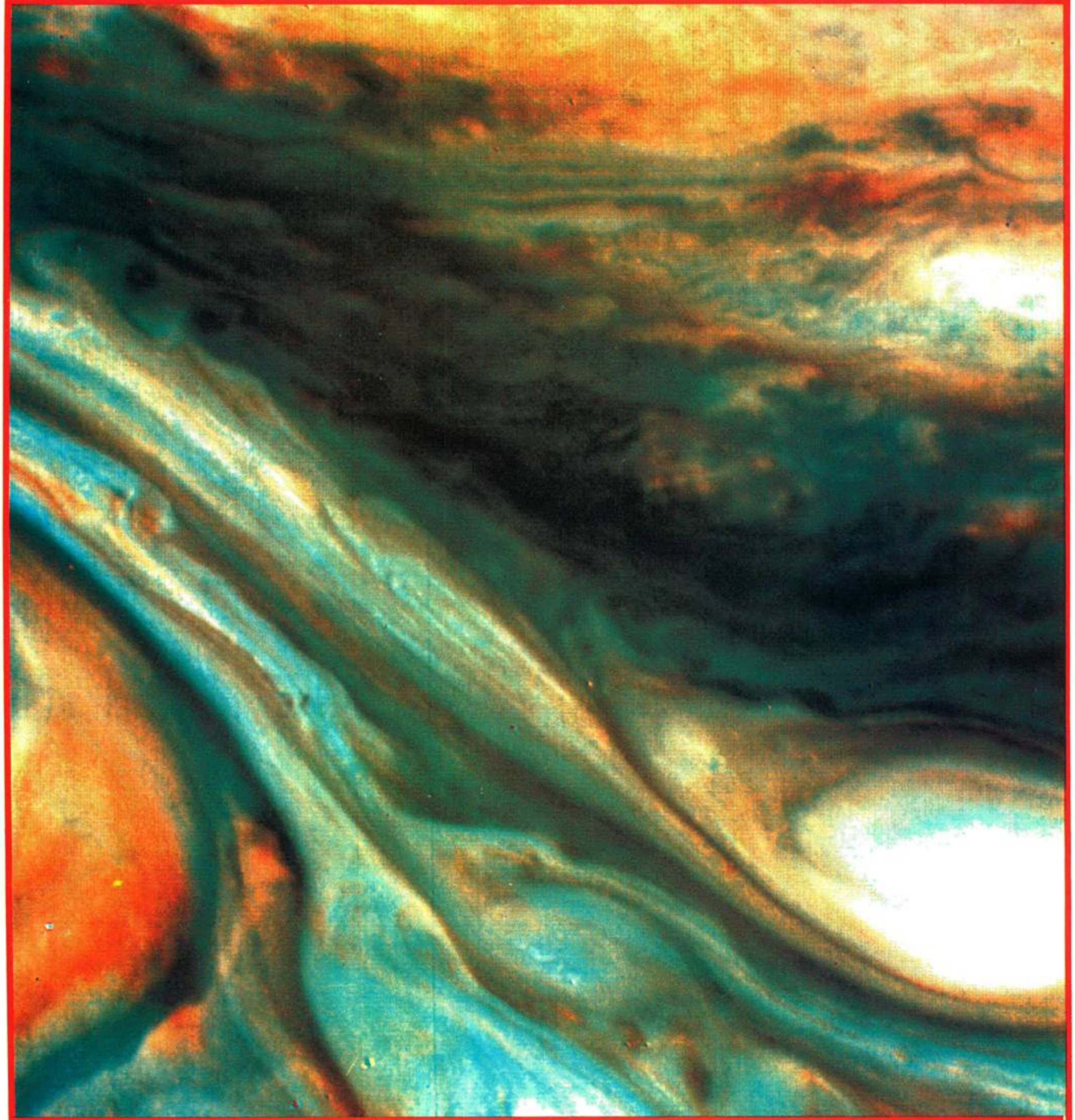
The Spot is oval in shape, with a length which varies from 18,000 to 25,000 miles on a time scale of a few years but a fairly constant width of under 9000 miles. It is also rather fixed in latitude, never having been observed to shift to the north or south from its position between 15 and 25 degrees south of Jupiter's equator. It isn't a surface feature, as was once thought, but lest there be any doubt about this, the Spot has been observed to shift significantly — and irregularly — back and forth in longitude. Over the past century it has wandered a distance equivalent to several times around the planet.

If the Great Red Spot is variable in size and — at least in one dimension — position, it is also quite variable in appearance. Over the years its color has changed considerably: sometimes a bright cherry red, at other times its color has faded almost to the point of invisibility. For example, it was quite prominent during the Pioneer 10 and 11 encounters in 1973 and 1974, but only a few years earlier it appeared quite pale and washed-out. By the time of



NASA/JPL photo

Jovian Winds



This Voyager 1 view of the region just to the east of the Red Spot (part of which is seen at left) is portrayed in greatly exaggerated color to enhance subtle variations in both color and shading. The deflection of the prevailing east-west winds around the Great Red Spot and the associated turbulence this produces stand out clearly. The Voyager cameras observed the white spot at right (like the Red Spot, a swirling jovian storm) swinging over and around the Red Spot in a matter of days. As an anticyclonic high pressure system in the southern hemisphere, the Spot shows a counterclockwise circulation pattern, completing a full rotation in about six days. The region above and at upper right displays the intricate complexity of a less violent area. NASA/JPL photograph P-21332, taken by Voyager 1 on March 6, 1979.

the Voyager flybys last year, its color had faded somewhat once again, and a Voyager 1 photo shows what seems to be clouds overlying the northern half of the Spot.

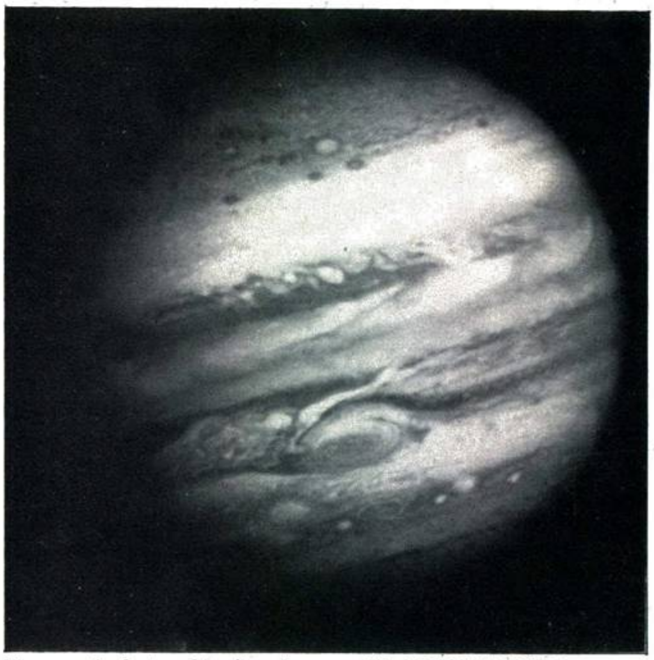
Even before the recent flybys, Earth-based observations in the infrared had shown that the Red Spot is cooler than the surrounding clouds. Since Jupiter's atmosphere, like Earth's, is colder at greater heights, this would indicate that the Spot is at a higher altitude, which might lend credence to the notion that the Spot is some sort of vast island floating in the jovian atmosphere. Unfortunately, it is rather difficult to imagine what sort of solid substance could float in an atmosphere consisting mostly of hydrogen — the lightest of all elements. Instead, scientists took this fact to mean that the material of the Red Spot was welling up from the deeper layers of the thick atmosphere and rising to a greater height than other features. But what could cause such an enormous upwelling? To understand that, we have to take a look at the planet as a whole.

Jupiter is quite clearly the giant of the Sun's family. Its mass — 318 times that of Earth — constitutes over two-thirds of all the matter in the solar system outside the Sun. Jupiter is so massive that scientists believe its tremendous gravity has enabled it to retain virtually the same composition as the original nebula from which the Sun and planets formed — mostly hydrogen and helium with only a smattering of the heavier elements. Thus although its volume is well over a thousand times greater than Earth's, its gaseous mass lags behind — only 318 times that of Earth. Its average density turns out to be only a little greater than that of water: 1.3 (water = 1, Earth = 5.5).

Jupiter rotates much faster than Earth, turning on its axis in less than half the time Earth takes. And the difference in rotation periods is even more important than it might appear at first. Jupiter's rotation period is just under 10 hours, but because of its enormous girth, the velocity of rotation at its equator is about 28,000 miles per hour — 28 times as fast as Earth's. One result of this (in combination with the low density of Jupiter) is that Jupiter is much more "flattened" by its rotation than Earth — fully twenty times as much, to be precise.

Jupiter is now believed to possess a small rocky core, about the size of Earth, composed of the heavier elements (such as iron) which sank to the center early in its history. But most of the rest of its bulk consists of hydrogen, in a liquid metallic form under the tremendous heat and pressure close to the core and in a liquid molecular form farther out. The shell of liquid metallic hydrogen surrounding the small rocky core is estimated to be about 24,000 miles thick. The next shell, in which the atoms of hydrogen are paired into molecules (H_2), forms an "ocean" 15,000 miles deep. The gaseous atmosphere above the surface of this liquid hydrogen sea is only about 600 miles deep, less than 1½% of the total radius. And what we see from Earth — or a passing spacecraft — is for the most part only the very tops of the clouds in this atmosphere.

This topmost visible layer is very cold: about -230° F. Of course, as we might expect, things would get warmer if we were to descend through the clouds to the denser levels below, just as they would on Earth. In fact, things get a *lot* warmer as we descend — remember, Jupiter has no solid "surface" like the terrestrial planets. By the time we reach the core, the temperature has climbed to an estimated 30,000 K — five times the temperature at the surface of the Sun! Astronomers who study very lightweight stars have calculated that if Jupiter were only a few times more massive, the central temperature and pressure could have been high enough to initiate thermonuclear reactions, and Jupiter would have been a star, a binary companion to our Sun.



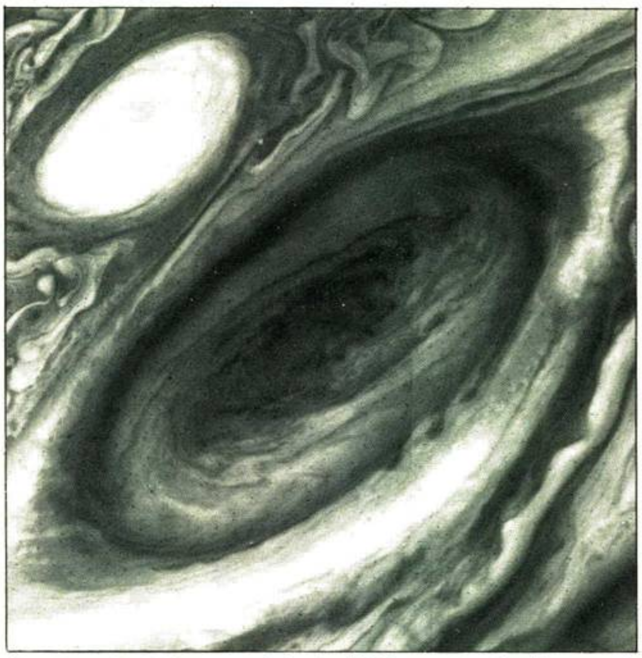
Voyager 1 photo of Jupiter, January 24, 1979 (NASA/JPL).

Of course, this did not happen. A star that failed to ignite its fires, Jupiter today is cooling, the immense heat of its formation slowly dissipating into space. Still, this almost-star manages to radiate just as much heat as it receives externally from the Sun. And this tremendous internal heat has great significance for the dynamics — and weather — of this huge spinning ball of gas.

On Earth, the dynamics of the atmosphere, and therefore our weather, are determined by a number of factors:

- The composition, depth, and density of the atmosphere.
- The heating of the atmosphere by solar radiation.
- The rotation of Earth on its axis every 24 hours.
- The 23½° tilt of Earth's axis relative to the plane of its orbit around the Sun.
- The character of the surface under the atmosphere: land and water, mountains and plains, forests and deserts, etc.

In every case we find the situation entirely different on Jupiter. The composition, depth, and density of the jovian atmosphere are totally different from Earth's, and while the 23½° tilt of our world's axis produces such enormous atmospheric effects as the seasons, Jupiter has only a minor, insignificant tilt of about 3°. We mentioned before that Jupiter rotates far faster than Earth, and as we might expect, this fact — especially in combination with the lack of a tilt in



The Great Red Spot on July 6, 1979 as seen by Voyager 2 (NASA/JPL photo).

the axis of rotation — is highly important in jovian atmospheric circulation.

The last factor (character of the surface) does not apply at all, for Jupiter, we now know, has no solid surface — just a planetwide ocean of liquid hydrogen — and therefore no surface features to influence its weather. And while Jupiter's atmosphere, like Earth's, is heated by the Sun, at the distance of Jupiter this radiation is only 1/25th as intense. But the real difference, and by far the most critical, is that unlike Earth, Jupiter has an internal source of heat fully equal or more than that received from the Sun. Now let's see what the meteorological effect of these very different jovian conditions is likely to be.

There is no seasonal variation on Jupiter to change the amount of heat absorbed by the northern and southern hemispheres. And since at least half of the heat pumped into the atmosphere comes from the interior of the planet, there is less of a gradient in energy input from the equator to the poles due to the angle of solar illumination. We would expect conditions such as these to encourage very stable atmospheric dynamics — a weather pattern less subject to change than Earth's.

The greater depth and density of the jovian atmosphere as well as the size of the planet as a whole insure that atmospheric phenomena will take place on a much larger scale than on Earth. And the greater heat capacity of this massive atmosphere must further encourage long-lasting features.

One of the most important factors in stabilizing jovian atmospheric dynamics is the lack of a solid planetary surface. Moving west or east on Earth brings change, from ocean to desert, or from mountains to forested plains, and such variations tend to break up any atmospheric formation moving across the face of Earth. But on Jupiter there is nothing to distinguish one point in longitude from another.

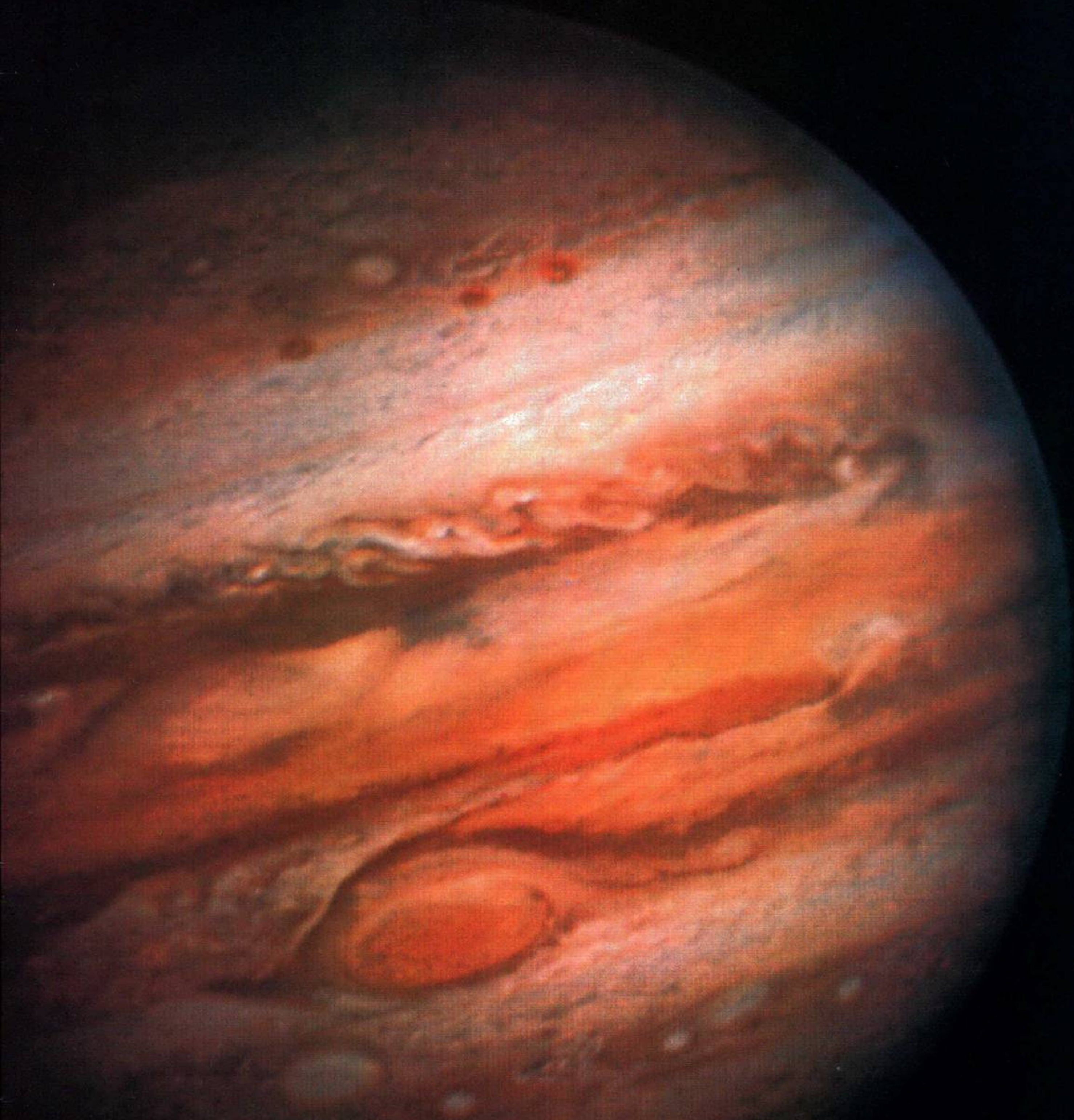
So we have a situation in which there is a lot of energy being pumped into a deep, thick, massive atmosphere on a giant planet which is spinning very fast, with no significant axial tilt and no solid surface features. The energy input, especially that from the interior, will result in rising and falling currents in the atmosphere, called convective currents. We would expect the spinning of the planet to draw out these currents into elongated bands, and in fact this is exactly what we see: the face of Jupiter is crossed by a series of alternating belts and zones, and we now know that neighboring bands consist of high-velocity winds blowing in opposite directions. We would also expect this pattern to be highly stable, changing only slowly if at all over the years, and again we find that this is so. Of course there would be irregularities and instabilities along the regions where neighboring currents flow past each other, and such violent turbulence was dramatically pictured by the Voyagers.

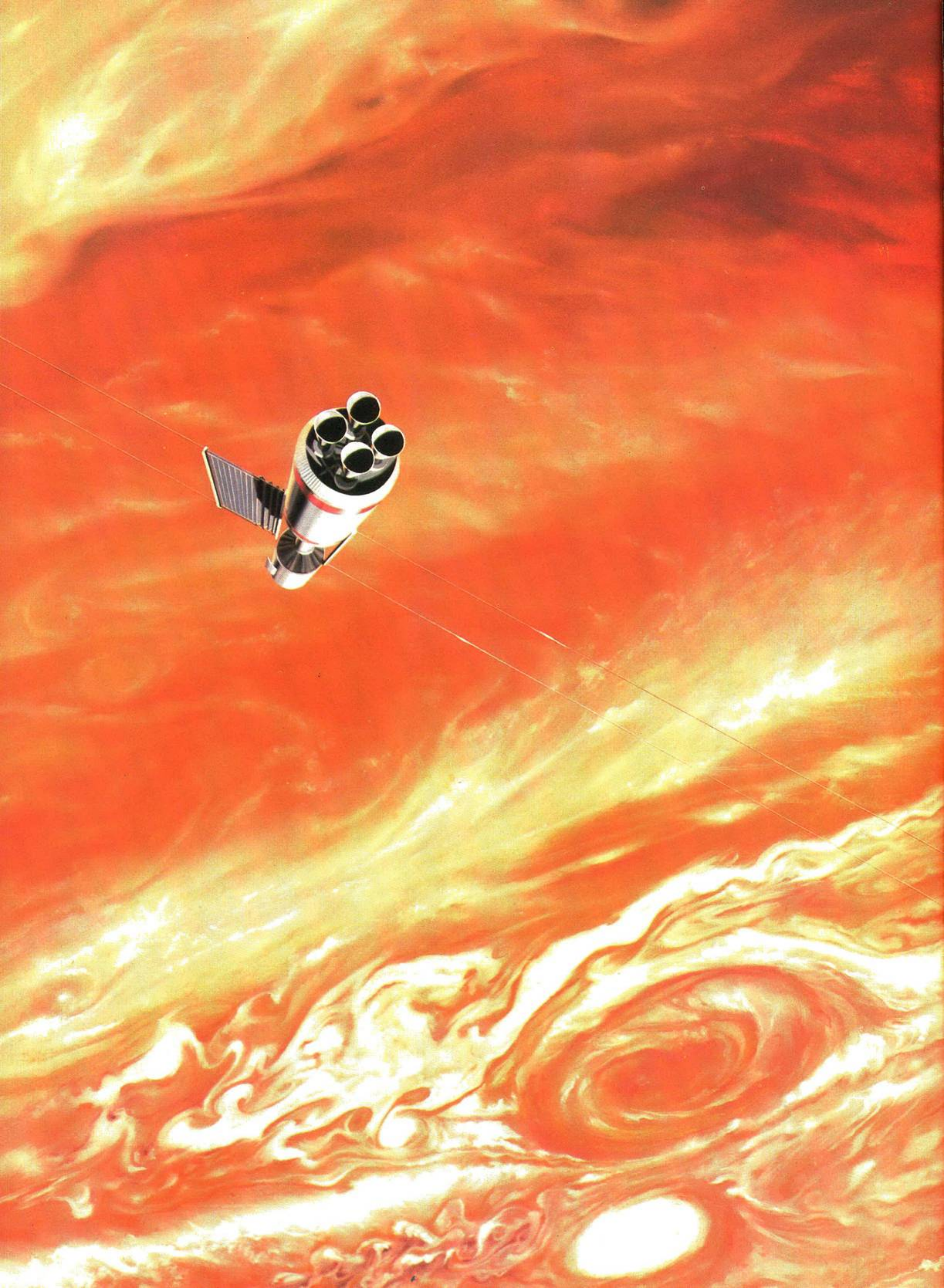
But still a number of questions remain. The Red Spot is in the southern hemisphere, which has a very different pattern of belts and zones than the northern (although there is a similarity in the pattern of alternating winds and their speeds). Is there a connection here? Is there something fundamentally different about the south which gives rise to the Great Red Spot? Why is the Spot red while other spots are not? And for that matter, why are there spots at all instead of an unbroken pattern of belts and zones?

In fact, there are also "spots" on Earth. These are regions of relatively higher or lower pressure in the atmosphere. The high pressure centers are marked by an expansion or spreading outward of gas, while in the low pressure centers gas flows inward to "fill up the hole," so to speak. But because of the spinning of the Earth, these flows are not moving directly into or out of the pressure center. Instead, the Earth's spin results in a force known as the Coriolis force, which redirects the flow pattern into a spiral circulation. This spiral pattern is like an S in the northern hemisphere and a reversed S in the southern. The direction of the winds, of course, will be into the center of the S in the case of a (low pressure) *cyclone*, and outward for (high pressure) *anticyclones*. Thus a terrestrial northern hemisphere hurricane (a low pressure center) is surrounded by winds which blow in a counterclockwise direction, while one in the southern hemisphere will have a clockwise circulation.

On Jupiter the Coriolis force is much greater because of the much faster rotation. We see a reversed-S spiral form in the Great Red Spot and we know that the flow pattern is outward, from the center to the edges, and therefore we can confidently identify it as a high pressure region: an anticyclonic storm. Voyager observations revealed a period of rotation of about six days. Of course it is a truly gigantic storm and an unusually long-lived one, but this makes sense in terms of the jovian conditions.

The Great Red Spot covers a portion of Jupiter over twice the size of Earth. With this Voyager 1 photograph and other pictures, scientists have detected a counterclockwise motion within the spot. Generally dark features on Jupiter are warm and light features are cold, but the exception is the Red Spot, the coldest place on the planet. It is believed to soar about 15 miles above the surrounding clouds. NASA/JPL photograph.





History of the Great Red Spot

Although the Great Red Spot of Jupiter has been known for over three centuries, it has not always been as familiar a jovian feature as it is today. It was first observed in 1664 by the English astronomer Robert Hooke and also studied by Giovanni Cassini at the same time. At that time it was called "Hooke's Spot." Seen intermittently over the next two hundred years, it was never recognized as a semipermanent feature. Each observation was regarded as independent, a sighting of a transient feature like so many others recorded. For example, the German astronomer Heinrich Schwabe carefully depicted the Spot in a drawing made in 1831, but failed to connect this particular spot with the previous observations of a similar feature.

We now know that the color of the Red Spot can change considerably over the years. Early astronomers, with their relatively primitive instruments, probably failed to pick it up during the times when its color had faded, and so its essential continuity was not recognized until late in the nineteenth century.

In 1878 Ernst Wilhem Tempel observed and described the Spot in detail at a time when its color had deepened considerably. Astronomers then realized that this spot was identical with the previous such spots observed, and it has been known as the Great Red Spot ever since.

Because of a strange practice engaged in by early scientists, some have thought that the Great Red Spot was observed as far back as 1611, right after the invention of the telescope. At that time it was customary to announce one's discoveries as Latin anagrams. The great scientist Galileo, who first turned the telescope toward the heavens, was no exception, but his anagrams were notoriously difficult to unscramble. He hid his observation of the phases of Venus in the line, "Haec immatura a me iam frustra leguntur o.y.," which literally means, "These are at present too young to be read by me, o.y." Of course the correct solution is "Cynthiae figuras aemulatur mater amorum" = "The mother of loves (Venus) imitates the figures of Cynthia (the Moon)."

Kepler, a great mathematician but not very adept at solving Galileo's puzzles, unscrambled the letters of the anagram to read: "Macula rufa in Iove est, gyratur mathem etc." This translates as "There is a ruddy spot on Jupiter, it rotates mathematically." This was not what Galileo meant, obviously, but did Kepler somehow know about the Red Spot? Although some have been suspicious, most historians agree with Owen Gingerich of Harvard that Kepler's proposed solution was accidental, a curious prophetic coincidence and nothing more.

Earthly storms, such as hurricanes, do not last long because eventually they drift over land, lose their source of water vapor, and quickly dissipate their energy by friction. Jovian storms, on the other hand, can't dissipate their energy so quickly, and so we would expect them to be much longer-lived — and the larger they are, the more energy they will have and so the longer they are likely to continue. This is borne out by a number of other observations, such as those of the white spots which first appeared just south of the Great Red Spot about 40 years ago. These have now been identified as high pressure anticyclones like the Great Red Spot. And again, a small red spot appeared in the northern hemisphere of Jupiter back in 1972 and lasted for about 2 years, long enough to be photographed by Pioneer 10 although it had vanished by the time of the Pioneer 11 flyby a year later.

We still have some unanswered questions. Why is the Great Red Spot red? Why aren't the smaller yet similar white spots also red? Could it be that the upwelling of the Red Spot is bringing up chemicals from deeper in the atmosphere? One candidate is a compound called phosphine (PH_4). This phosphine is broken down by sunlight into free hydrogen and red phosphorus. Very high clouds on Jupiter, exposed to the ultraviolet radiation which can't penetrate very far, would thus be expected to turn red, and the Great Red Spot is simply an enormous example of this.

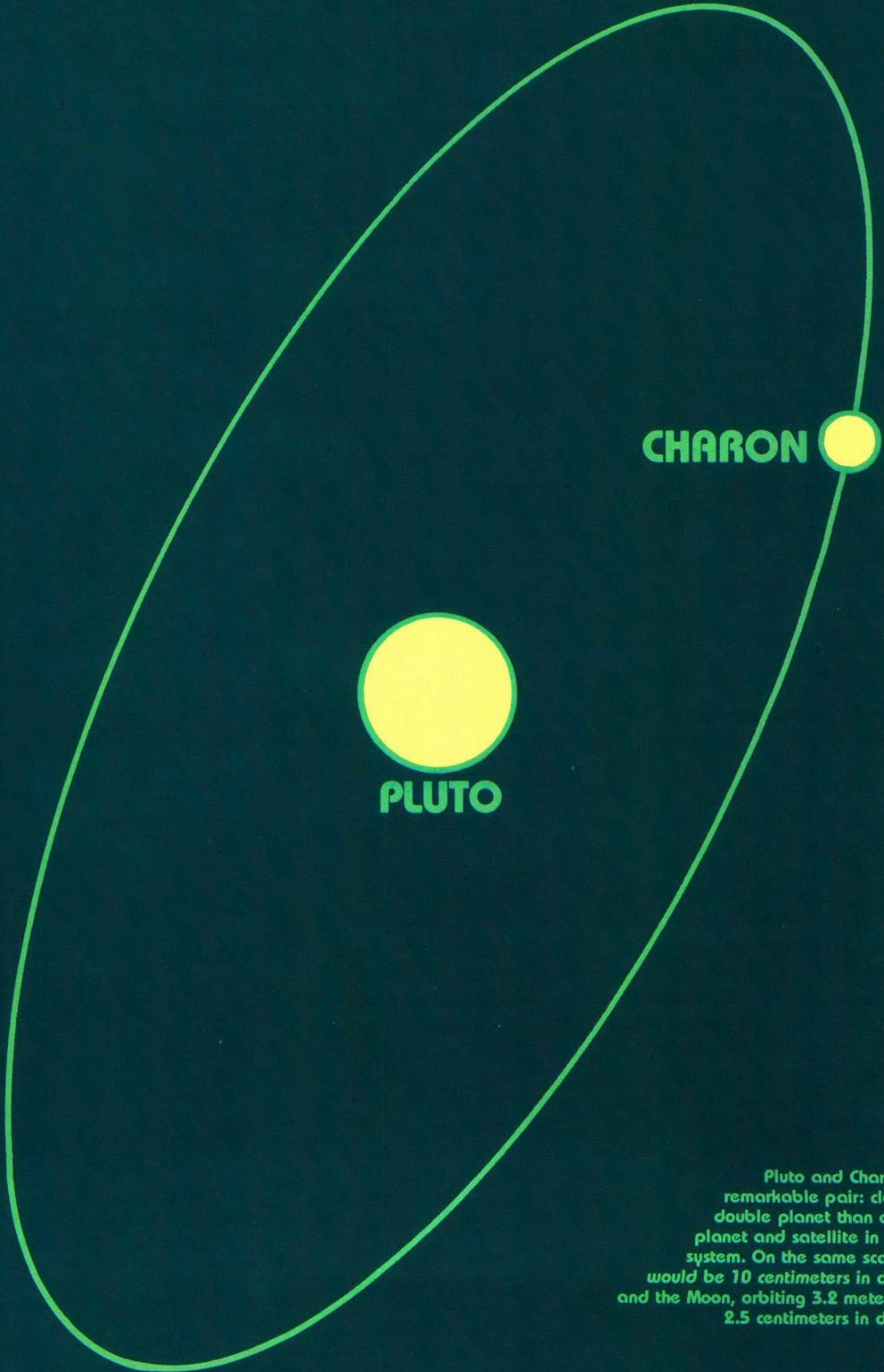
Why are there circulating spots at all? It seems that most spots are formed by the shearing action occurring between two regions of opposite flow, but it is hard to account for the formation of a spot as large as the Great Red Spot by this mechanism. Some other as yet unknown process may be at work.

And finally, why is there an apparent difference in the atmospheric dynamics of Jupiter between the northern and southern hemisphere? Is this asymmetry due merely to chance, or is there some literally deeper cause? No one yet knows. We can now say with confidence that the Great Red Spot of Jupiter is actually a huge anticyclonic storm caused by the dynamics of the solar system's most enormous atmosphere. The exact mechanism leading to its formation and the processes maintaining it remain somewhat unclear, but there is a great deal of data from last year's Voyager mission still to be studied. And the Galileo mission, scheduled to arrive in the jovian system in 1986, will return a wealth of new observations.

One especially valuable aspect of this mission will be the probe dispatched from the Galileo mothership into the atmosphere of Jupiter. This probe will descend through the various layers of the jovian clouds, "tasting" the gases and telling us what chemicals are present, measuring the increasing density, temperature, and pressure until it is crushed and destroyed deep in the atmosphere. It may be that then some of the remaining mysteries surrounding the Great Red Spot and the solar system's largest weather system will be solved at last.

— Dewey Schwartzenburg

In the artist's conception seen on the facing page, a spacecraft of the future approaches the solar system's largest planet and prepares to examine the Great Red Spot up close. Painting by Paul Hudson.



Pluto and Charon are a remarkable pair: closer to a double planet than any other planet and satellite in the solar system. On the same scale, Earth *would be 10 centimeters* in diameter, and the Moon, orbiting 3.2 meters away, 2.5 centimeters in diameter.

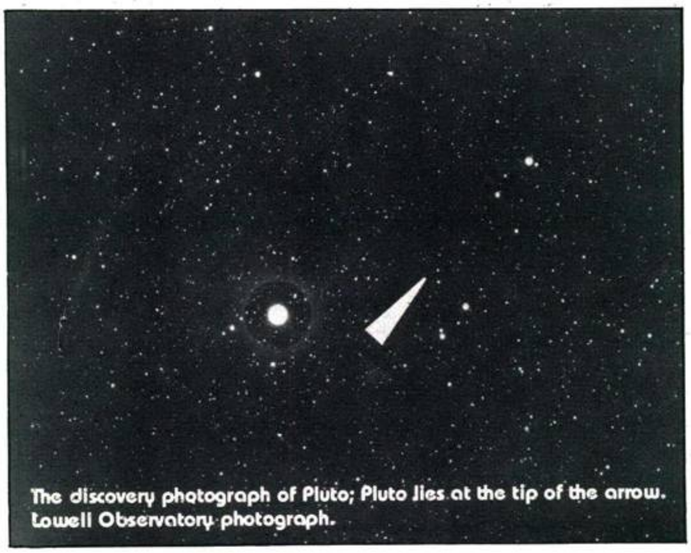
MYSTERIOUS PLUTO

More than fifty years after its discovery, Pluto remains a mystery. Even such basic information as its mass and diameter were not determined until the late 1970s; we know very little else with any certainty. A satellite of the planet escaped detection, despite being photographed several times a decade. Why, in the age of space flight, did a major planet discovered half a century ago continue to be such an unknown quantity for so long? For those who have actually looked at Pluto through a telescope, the answer is obvious: Pluto is so remote that it is only a faint speck of light in terrestrial telescopes.

Discovery — and Disappointment

Orbiting in the outer reaches of the solar system, Pluto remained unknown — but not unsuspected — until 1930, when a systematic search by astronomers at Lowell Observatory distinguished it from tens of millions of faint stars that look just like it. Not satisfied with the celestial mechanics of Uranus' and Neptune's orbits, those astronomers who suspected Pluto's existence had postulated another planet beyond Neptune. They expected a gas giant, a planet with a mass many times that of Earth. They expected a planet fainter than Neptune, of course, but one about ten times brighter than Pluto actually turned out to be.

Almost immediately they knew they hadn't found what they were looking for. Pluto was too faint, and even with the most powerful telescopes it showed no visible disk. It was a mere point of light, like a star, and a very faint one at that. Calculations based on the greatest size it could have without showing a disk, and a guess at its mass, showed the planet would have a much greater density than lead. Astronomers could not accept such a planet — but there it was.



The discovery photograph of Pluto; Pluto lies at the tip of the arrow. Lowell Observatory photograph.

Furthermore, its orbit wasn't what they expected. The real Pluto was too close to the Sun, its orbit more elliptical than that of any other planet — elliptical enough to bring it closer to the Sun than Neptune at times. And it was inclined to the plane of the other planets by 17° — more than any other planet. What could such irregularity mean?

Over the next few decades, the estimates of Pluto's mass kept dropping as it became apparent that Pluto's gravitational effect on the other outer planets was very small. Meanwhile, the diameter estimates dropped too, because the reflectivity of 4% (as black as coal) which astronomers had calculated from the brightness of the planet (plus the assumption that it was the same size as Earth) seemed unrealistically dark for a planet that was likely to be snow-covered.

And there the matter sat.

Pluto the Remote

In the late 1940s and early 50s, careful new visual observations made with the 200-inch telescope on Palomar Mountain brought the diameter down still further — to about half Earth's size. This new estimate raised the reflectivity to 17% — about as dark as an asphalt sidewalk — which was relatively acceptable. Other astronomers found that Pluto's light varied by about 10%, in a cyclical pattern, implying that the planet rotated about once every six days.

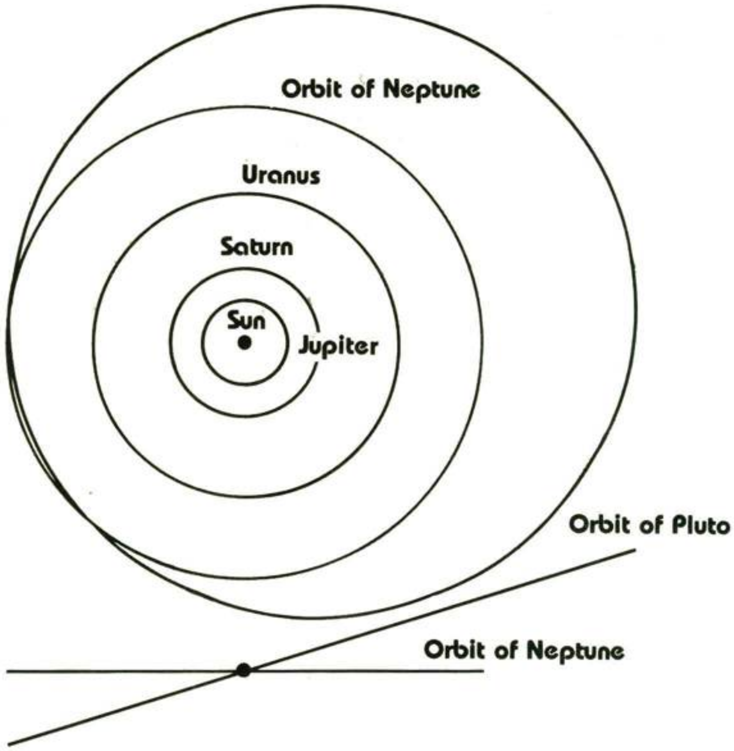
Again the matter sat. Mysterious Pluto defied the astronomers. It was too faint and too remote for detailed study. Orbiting in its strangely inclined orbit at the edge of the solar system, it was without enough mass to affect the other planets, too small to permit accurate measurement of its size, too faint to permit accurate spectra of its light, and rotating slowly. The numbers in the textbooks proposed for its mass and diameter were little more than educated guesses.

New Instruments

New astronomical techniques and equipment in the 1960s and early 70s brought some refinements. Using powerful digital computers, celestial mechanicians traced the orbit of Pluto millions of years into the past and future. Its orbit is in resonance with Neptune's: for every three revolutions Neptune makes, Pluto makes two. Computer runs showed that Pluto never passes closer than 18 astronomical units from Neptune — and that its orbit could have been stable for the entire age of the solar system.

Sensitive light detectors enabled astronomers to refine the rotation period: 6.38673 days, with an error not exceeding a minute. It also appeared that Pluto was slowly

Pluto's Orbit



semimajor axis	39.53322 astronomical units
period	248.56689 years
inclination to ecliptic	17.122886 degrees
orbital eccentricity	0.2460034
time of perihelion	September 1989
orbital velocity (average)	4.7 kilometers per second
distance from Sun at perihelion	29.58 astronomical units
distance from Sun at aphelion	49.49 astronomical units
Pluto closer to Sun than Neptune	January 23, 1979
Pluto farther from Sun than Neptune	March 15, 1999

Pluto's orbit suggests that it is a large remnant primordial body — a planetesimal — from which we think all the planets were built. It escaped, by chance, from accretion onto Neptune during the early days of the solar system. Why Pluto? Among the thousands of similar primordial bodies that may have once orbited in the outer part of the solar system, it just happened to be in orbital resonance with the fastest-growing and largest planetesimal, the object that became Neptune. For every two revolutions Pluto makes, Neptune makes three; and the two never pass close to each other.

growing darker, and had been doing so since the 1950s. A few crude infrared spectra — their accuracy limited by the light available from the planet — led astronomers to suspect the surface might be covered with a layer of methane frost.

Meanwhile, astronomers tried another approach to finding Pluto's diameter: stellar occultations. Every few years, Pluto passes in front of a star and blocks its light. From the duration of the eclipse, measured at several observatories, it is possible to find Pluto's diameter. One such opportunity almost occurred, but Pluto missed the star. However, if Pluto had been bigger than 6800 kilometers diameter, an occultation would have been seen. This put a new upper limit on its size.

The Discovery of Charon

Our knowledge of Pluto might have remained fragmentary until the beginning of the 21st century (the earliest, by any reasonable schedule, a spacecraft could orbit out to it), if Pluto's satellite Charon had remained undiscovered. But it did not; in 1978 James Christy, an astronomer at the U.S. Naval Observatory, noticed a distortion — a little bump on the side — in images taken of Pluto for precision position determinations. The bump seemed to shift back and forth, appearing on one side of Pluto, then three days later on the other, and a little more than six days later on the original side.

The study of Pluto was transformed. One major breakthrough followed another as the physical nature of this lonely outer planet became accessible. What happened? The bump was the unresolved image of a satellite orbiting Pluto — and the satellite, soon named Charon, was the key to the mysteries of Pluto.

Charon's period of revolution is the same as Pluto's rotation. Its distance from Pluto, difficult to measure accurately from the tiny fuzzy images on the plates, is around 17,000 kilometers.

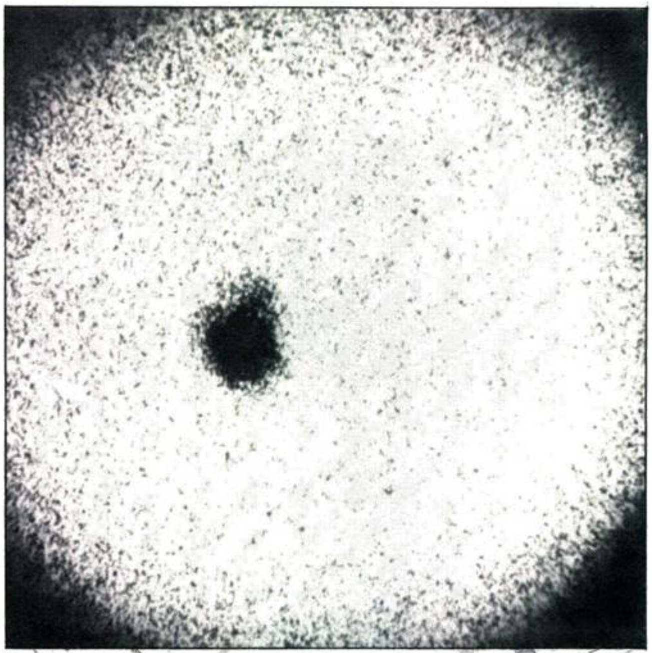
Pluto Weighed

With the discovery of a satellite, finding the mass of Pluto was a simple matter of plugging the orbital period and distance of the satellite into Newton's modifications of Kepler's third law of planetary motion: from that equation would come the sum of their masses. The best result, still somewhat uncertain because of the difficulty of obtaining a precise measurement of the orbital radius, is about 10^{25} grams, or about 1/600th the mass of Earth!

Pluto and its satellite turned out to be very much lighter than many astronomers expected. Earth's natural satellite, the Moon, is about 1/80th Earth's mass; Pluto, therefore, is around 1/8th the mass of the Moon. Charon, which is about 1/6th the brightness of Pluto, is somewhere around 10% of Pluto's mass.

Pluto's diameter has now become much better known (or at least much closer to being known) even though it cannot be telescopically resolved any better than it was in the past. What has suddenly changed (now that the mass is known) is that sophisticated guessing — based on plausible mixes of materials that Pluto could be made from, combined with an understanding of how those materials behave in the core of a planet — places limits on how big and how dense Pluto can be.

Consider what we know about Pluto as it stands now: we know how much light is reflected from it, and we know the mass of the planet — at least reasonably well. We cannot measure its diameter directly, but because we know the brightness, the reflectivity of the surface and the diameter — which control how bright Pluto looks to us — are inextricably linked. If Pluto is 100% reflective, it has to be 2160 kilometers in diameter; if it's 50% reflective, the planet must be 3060 kilometers in diameter; and for 25% reflectivity, Pluto would be 4320 kilometers in diameter.



The discovery photograph of Charon. United States Naval Observatory photograph.

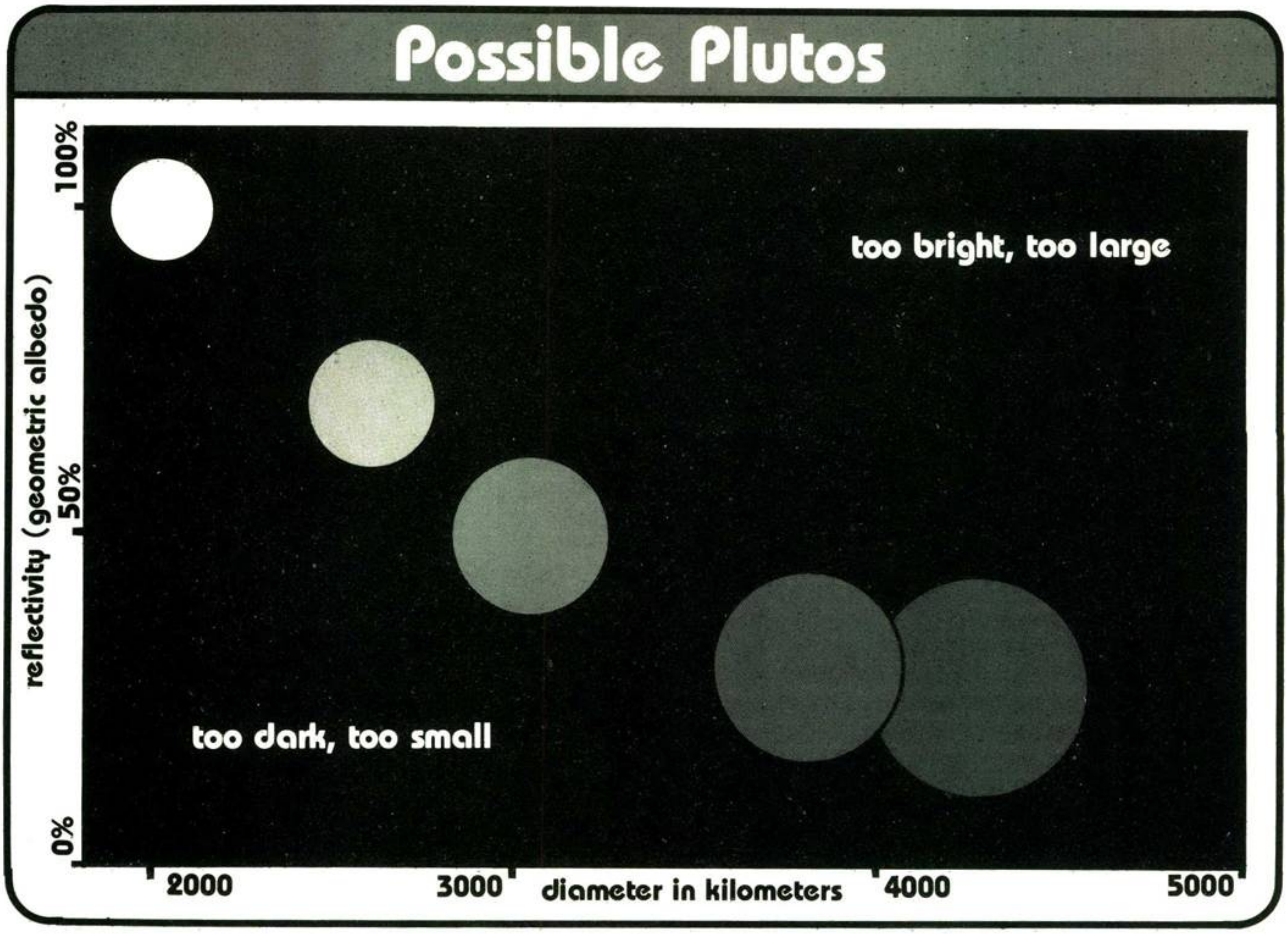
Pluto's Icy Glitter

How reflective is the surface? We don't know, but we think — based on its infrared spectrum — that it's probably covered with a fairly bright methane frost. But even bright, clean frosts are only about 70% reflective, immediately placing a limit on the smallest size.

We can also limit the diameter in other ways. The bulk density of Pluto, that is the total mass divided by the volume of the planet (which depends on its diameter), cannot realistically exceed certain limits. If Pluto were 6800 kilometers in diameter, as the upper limit of the occultation measurements suggested, its density would be 0.04 grams per cubic centimeter (water is 1.0). Very few solids have such a low density, not even styrofoam, so we can immediately rule out so large a diameter.

In fact, an extreme upper limit to the diameter can be set by assuming that Pluto is a solid ball of methane ice. At half the density of water, methane ice is the least dense plausible material for building a planet available in the outer solar system. The result is a planet 3820 kilometers in diameter (the upper limit) with a reflectivity of 32%.

Is it realistic to think of Pluto as a ball of pure methane? As we look farther from the Sun's heat into the solar system, we see more of the lighter, more volatile materials. The outer satellites of Jupiter are rocky objects; the satellites (as well as the rings) of Saturn are water, with rocky materials. The satellites



of Uranus are covered with water ice. Beyond Uranus, we see methane — a tenuous methane atmosphere around Neptune's satellite Triton and the methane frosts on Pluto. Yet in the primordial solar nebula, methane should not have been so abundant to form an entire planet without the inclusion of other materials — especially water, already common in the outer solar system, and some silicate rock.

Inside Pluto

Computer modeling, taking into account many complexities — the liberation of heat by radioactivity in the core rocks, the conduction of heat through the planet, compression and melting of water ice inside the planet, the mechanical strength of methane ice (which is very weak), internal convection (possibly leading to methane volcanos and plate tectonics on this frozen little world) — has generated scores of possible Plutos, all Plutos that are plausible and don't contradict anything we think we "know" about Pluto.

The best family of models shows Pluto with a core about 1200 kilometers in diameter, made of silicate rock, and about one-fourth of Pluto's mass. Nearly three-fourths of the mass of the planet would be in a blanket of water-ice 650 kilometers thick, covered with a 50-kilometer shell of methane ice contributing about 3% of the planet's mass. Other models in this family have more massive methane layers up to 700 kilometers thick. The best model of Pluto has a bulk density of 1.12 grams per cubic centimeter, a diameter of 2600 kilometers, and a reflectivity of 70%.

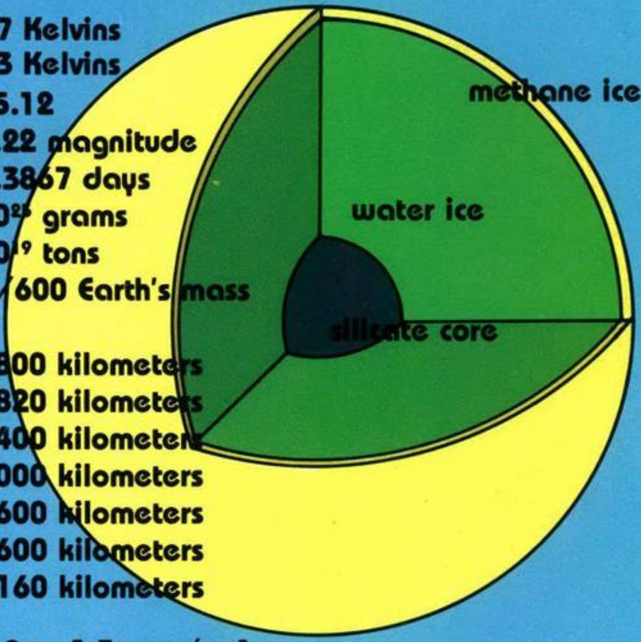
Keeping Pluto bright enough to satisfy this model is a bit of a problem. Under the action of sunlight, even at the great distance of Pluto from the Sun, methane decomposes into hydrogen and carbon soot, and could decrease its reflectivity from the 70% of clean fresh snow to a dingy city-snow gray. Is there a way to renew the methane more or less continuously, to refurbish it, or shine it up? If, for example, during each plutonian day some methane evaporated then "fell" as a frost each night, we could plausibly renew the surface.

A Breeze of Methane

But this touches on another not-so-simple problem, that of Pluto's atmosphere. There are two contradictory lines of thinking, one pointing toward an atmosphere and the other away from it. If Pluto does have an atmosphere, we would expect its molecules to scatter blue and violet light well, as Earth's atmosphere does. Even in the very lowest-resolution spectra, Pluto should show a small excess brightness in the blue and violet part of the spectrum. It does not — and this imposes an upper limit to Pluto's atmosphere.

However, Pluto's surface is at least partially covered with methane ice, and recent spectroscopic observation suggests "more than a trace" of atmospheric methane gas may exist. Now that we know Pluto's mass and radius, we know that the escape velocity is very low. An atmosphere of a gas as light as methane would blow off into space in a matter of days to weeks. Over the age of the solar system, in fact, an enormous amount of methane — as much as a

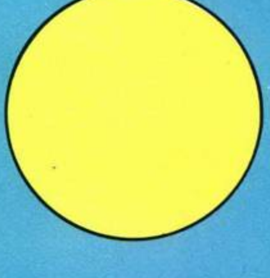
Pluto Data



average surface temperature	37 Kelvins
daytime surface temperature	43 Kelvins
visual magnitude (1972)	15.12
amplitude of brightness variation	0.22 magnitude
period of rotation	6.3867 days
mass (best estimate)	10^{25} grams 10^{19} tons 1/600 Earth's mass
diameters:	
upper limit, 200" direct measure	6800 kilometers
upper limit, ball of pure methane	3820 kilometers
via photometric properties	3400 kilometers
based on speckle interferometry	3000 kilometers
based on internal composition model	2600 kilometers
lower limit, fresh snow surface	2600 kilometers
lower limit, 100% reflectivity	2160 kilometers
density (best estimate)	1.0 to 1.5 gms/cm³
surface cover	methane ice
brightness of Sun from Pluto	−19 magnitude
radiation input from Sun	1/1600 Earth's

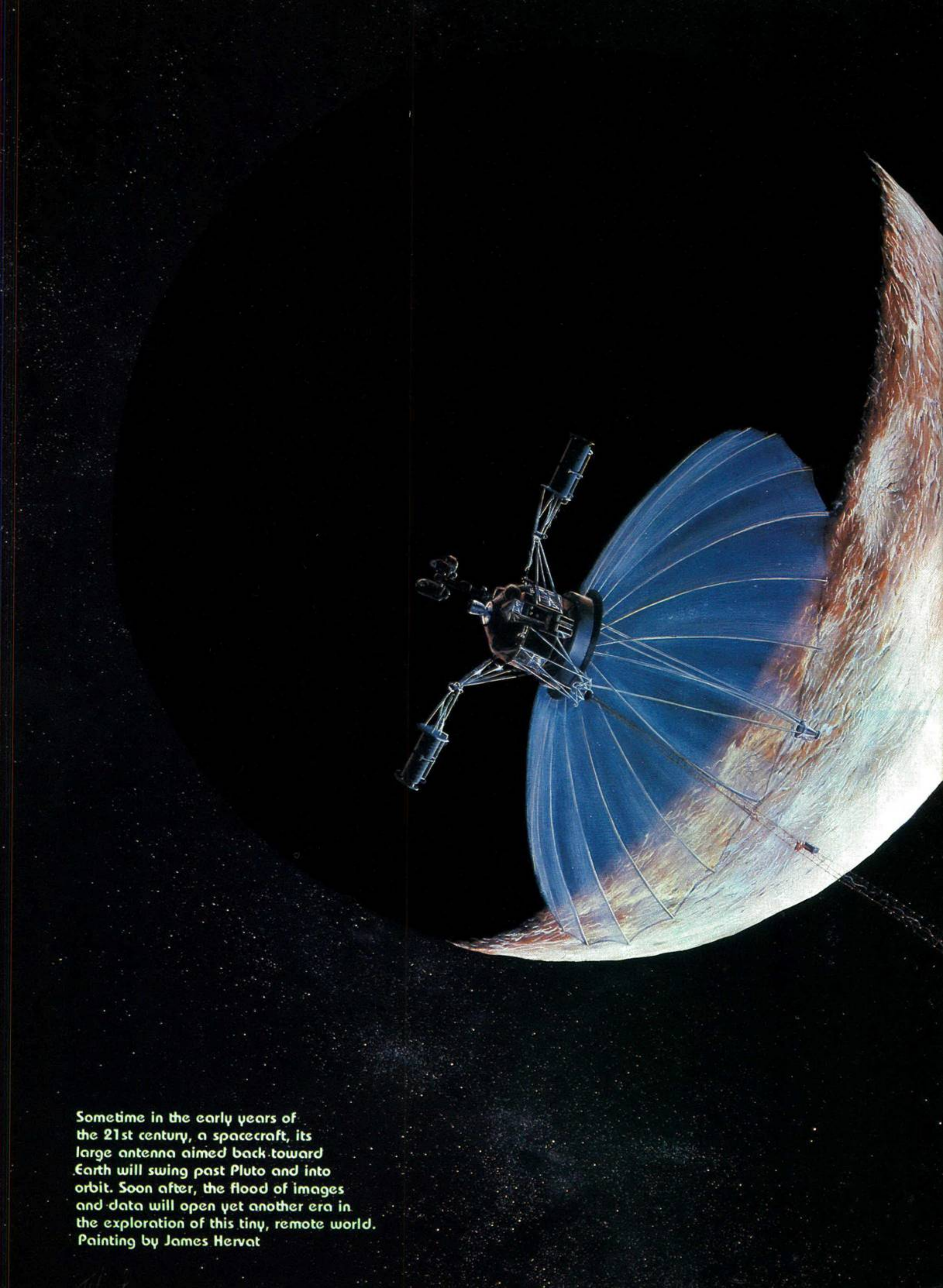
name: god of the underworld (Hades) in Roman mythology
date of discovery: February 18, 1930
discoverer: Clyde Tombaugh

Charon Data



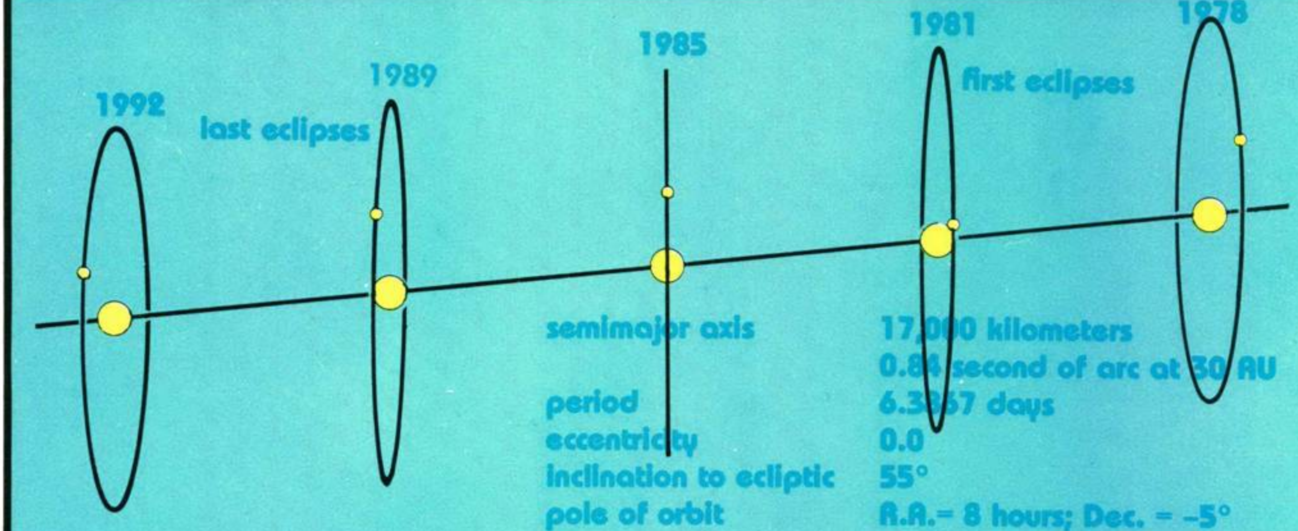
mass	10^{24} grams 1/6000 Earth's mass about 10% Pluto's mass
distance from Pluto	17,000 kilometers
diameters:	
based on brightness	40% that of Pluto
lower limit, occultation	1200 kilometers
visual magnitude	16.8

name: ferryman who carried the souls of the dead across the river Styx to Hades, the kingdom of Pluto
discovery date: June 22, 1978
discoverer: James Christy



Sometime in the early years of the 21st century, a spacecraft, its large antenna aimed back toward Earth will swing past Pluto and into orbit. Soon after, the flood of images and data will open yet another era in the exploration of this tiny, remote world. Painting by James Hervat

Charon's Orbit



semimajor axis	17,000 kilometers 0.84 second of arc at 30 AU
period	6.3867 days
eccentricity	0.0
inclination to ecliptic	55°
pole of orbit	R.A.= 8 hours; Dec. = –5°

Charon's orbit about Pluto is stable and apparently the satellite is tidally locked to Pluto's rotation. Tidal friction would have slowed Pluto from an initial rotation period of approximately 10 hours.

layer hundreds of kilometers thick — could have escaped from Pluto.

For hundreds of millions of years, Pluto could have been evaporating away. Some of the heavier components, such as argon and nitrogen, of this outpouring would have been retained, and would today form a "blanket" to hold in enough methane to show up spectroscopically. But such a blanket would cause Pluto to show excess blue brightness, which is contradicted by the present observations. Does Pluto have an atmosphere? We simply don't know yet — and maybe we should rephrase our question: "How *much* of an atmosphere does Pluto have?".

Sharpening the Picture

Meanwhile, of course, astronomers are working hard to confirm the diameters they have gleaned by other techniques. A special technique called "speckle interferometry" allows the reconstruction of a sharp image of double stars and the determination of diameters of objects from hundreds of very brief exposures that freeze our turbulent atmosphere. Applied to Pluto, this technique gives a diameter of 3000 kilometers if Pluto is bright at the limb, and 3600 kilometers if it's darkened. These determinations suggest a rather low reflectivity (around 40%) and a density approaching the "pure methane ball" models.

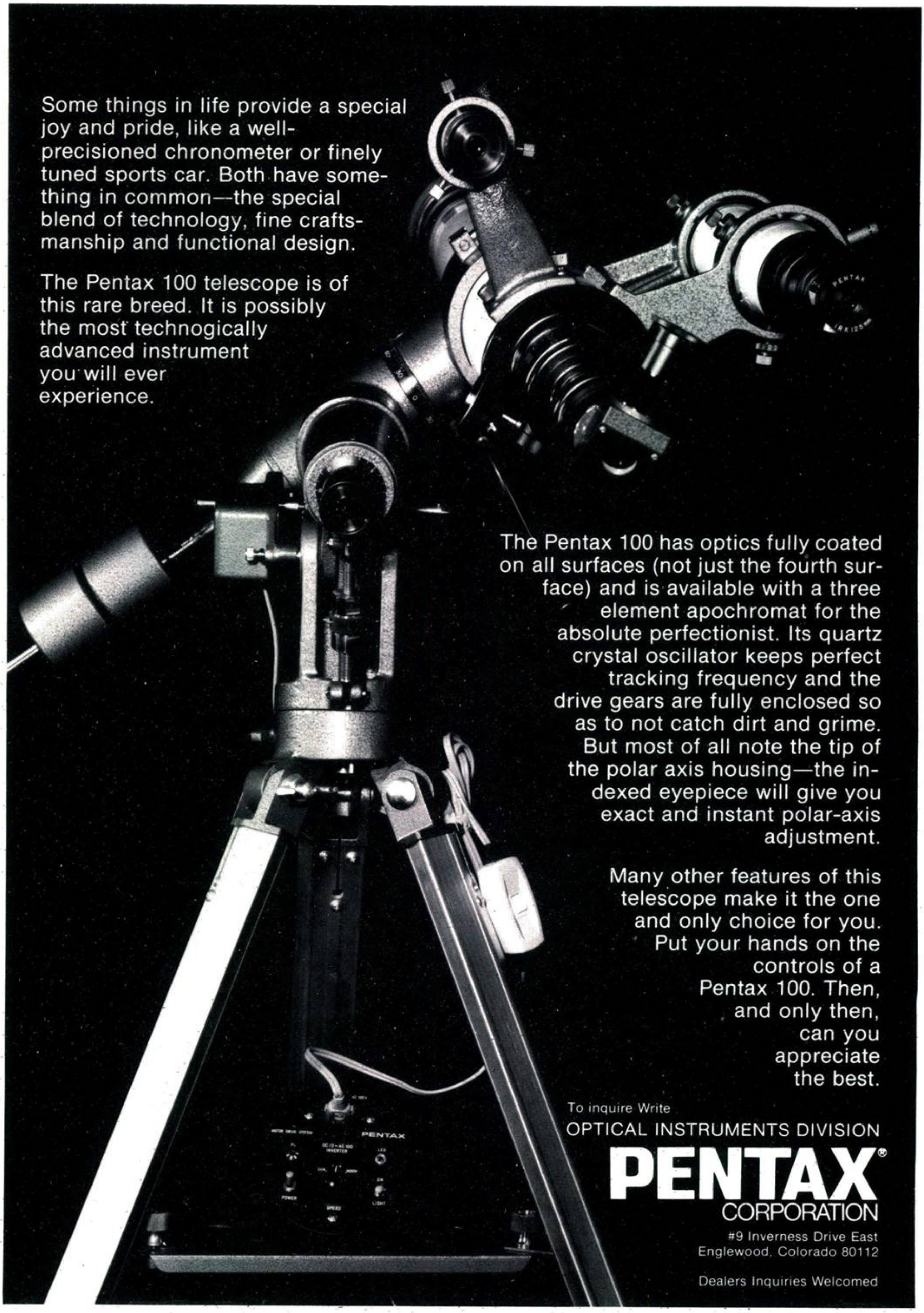
Recently the occultation method was tried again. On April 6, 1980, Pluto passed a star of about 12th magnitude, and as before, Pluto failed to occult it. But Charon apparently blocked the star's light, for observers in South Africa, for 50 seconds. While not yielding any new information about Pluto, this places a lower limit of 1200 kilometers on Charon's diameter. If Charon has the same surface reflectivity as Pluto, its diameter, on the basis of its brightness, should be about 40% that of Pluto, or 1100 to 1500 kilometers in diameter.

During the next five years, we're going to see a sharp picture of Pluto. But how? How are we to know, within our lifetimes, what Pluto really looks like? No spacecraft is likely to go there this century. Even the Space Telescope, that orbiting high-resolution pride and joy of astronomers, when it photographs Pluto and Charon during the 1980s, will have only a resolution of about 1200 kilometers. That's terrible — barely enough to show the maria on the Moon! Yet there is a way to make a sharp picture of Pluto from the Earth.

Sometime around 1985, plus or minus 3 years, the orbital plane of Charon will pass through the Earth. For roughly three years before and three years after, 112 times per year, Charon will eclipse Pluto or Pluto will eclipse Charon. The first eclipses could be as early as 1980 or as late as 1986 — Charon's orbit isn't well enough known yet to tell any better. But Charon and Pluto will act as probes of each other's surface brightness, photometrically peeling away thin layers of each other's surface. By measuring the light from dozens of eclipses, then solving a giant array of equations with a large computer, astronomers can hope to know the brightness of each point on one hemisphere of Pluto and Charon — and make a picture of that data.

The eclipse data will also produce very accurate measurements of the diameters, shapes, and orbital distance (therefore, the mass and density) of both Pluto and its moon to high precision. While Pluto will long remain a mystery — for we've barely even touched on its origin, its orbit, or its history — the mystery of its size, its mass, and its appearance will soon be solved. *For Pluto, then, the next few years* promise to very interesting indeed.

— *Richard Berry*



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ASTRONOMY FORUM

Predictions in Collision

The true test of a new scientific model lies in its ability to make testable predictions which are at variance with expectations based on accepted models of the universe. This is the claim of one of the great pop-science notables in the past thirty years, Dr. Immanuel Velikovsky. He claims that his reconstruction of ancient interplanetary catastrophes, backed by voluminous references to worldwide myths and legends, has been verified by discoveries from space probes. But has it?

"The space age gave my views a record of confirmations," he wrote in 1977. One of his chief disciples was even more specific: "Seldom in the history of science have so many diverse anticipations — the natural fallout from a single central idea — been so quickly substantiated by independent investigation." So wrote Ralph Juergens in September 1963.

But this attitude is baffling to many space scientists, those who have actually obtained the data from those space probes. Replying to the assertion that space exploration had verified Velikovsky's theories, Dr. Carl Sagan told a San Francisco seminar in 1974: "To the best of my knowledge, there is not a single astronomical prediction correctly made in *Worlds in Collision* with sufficient precision for it to be more than a vague lucky guess and there are...a host of claims made which are demonstrably false." Space scientist (and ASTRONOMY author) David Morrison goes on: "Every important prediction he [Velikovsky] made in 1950 concerning conditions on the planets, such as hydrocarbon clouds on Venus, large amounts of argon in the atmosphere of Mars, recent melting of the lunar surface, large internal heat sources on Venus and perhaps Mars, large-scale recent cratering of the Earth and Moon, and synchronized planetwide volcanism on Earth, has been shown decisively to be in error...Every new space mission, such as the recent Pioneer-Venus probes, pounds another nail in the coffin...The cruel truth is not only that astronomical evidence fails to support Velikovsky, but that a great deal that seemed plausible or at least possible when suggested in 1950 has been shown to be incorrect."

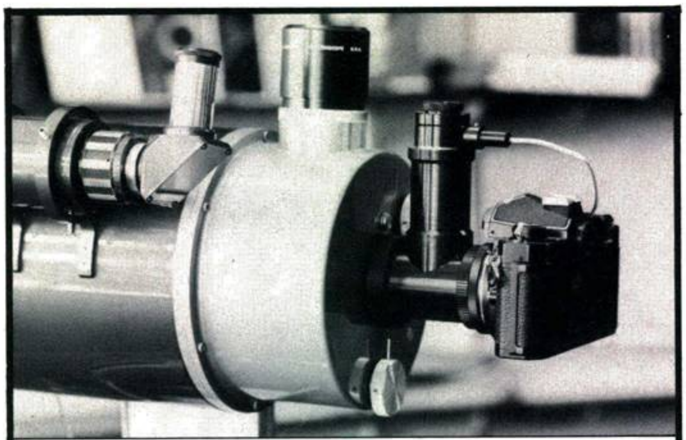
Dr. Velikovsky died at age 84 last November. His most widely known book, *Worlds in Collision* (published in 1950), established him as a nonconformist in the scientific world. During his lifetime, he attracted avid followers — and strong detractors. Perhaps now is the time to examine the planetary predictions he made, and remade, in light of what was actually discovered, and compare them to space data. By concentrating on the "confirmation" of specific predictions, we may now be able to see which were significant and which were coincidence, lucky guesses, or Monday-morning-quarterback revisions of ambiguous theorizing. We will not consider Velikovsky's unusual theories of ancient history, and we will, especially, be critical of fuzzy predictions which could be interpreted *ex post facto* to mean anything.

> **"...there is not a single astronomical prediction correctly made in** Worlds in Collision **with sufficient precision for it to be more than a vague lucky guess..."**

The Earth's Moon played a significant role in Velikovsky's scenarios of planetary encounters. Most prominent among his successful predictions were those of "numerous moonquakes" and "lunar remnant magnetism," both made in the face of the expectations (or lack of them) of establishment science.

Here is what Velikovsky wrote about the possibility of moonquakes, using the July 21, 1969 issue of the *New York Times* as a forum: "I also maintain that moonquakes must be so numerous that there is a bit of chance that during their few hours on the Moon the astronauts may experience a quake." The astronauts, of course, did not "experience" (i.e., "feel") a moonquake nor did subsequent astronauts — nor would they if they had stayed for millions of years.

As it turns out, moonquakes are very weak and very rare. Only because of their extreme sensitivity and the high seismic conductivity of the super-dry lunar surface, did the Apollo seismometers detect any moonquakes. At every comparable level of intensity, the Moon is a much, much quieter place than Earth; Velikovsky's descriptions of the Moon and the astronauts' chances of encountering moonquakes were both in error. But a few years later, it sounded as if he had been right on target: "He said only that quakes would be numerous," wrote follower Dr. C. J. Ransom in 1975, "and did not *suggest that they would* be of great magnitude." A skeptic is justified in wondering that if this is the case, how did Velikovsky expect the



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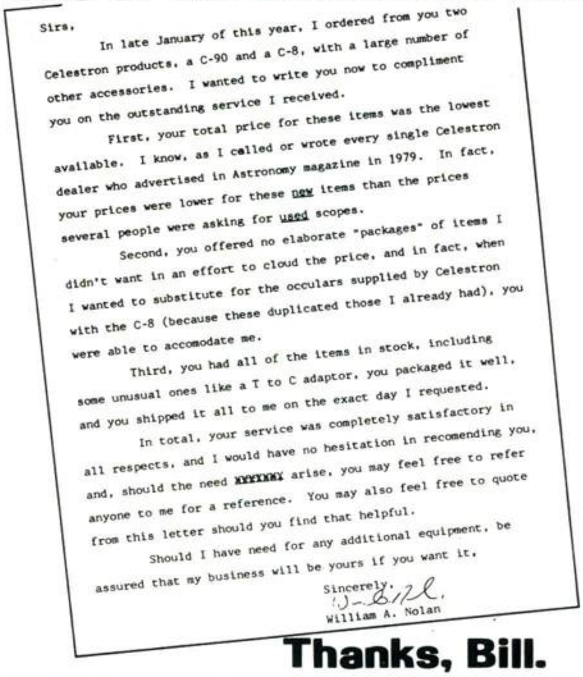

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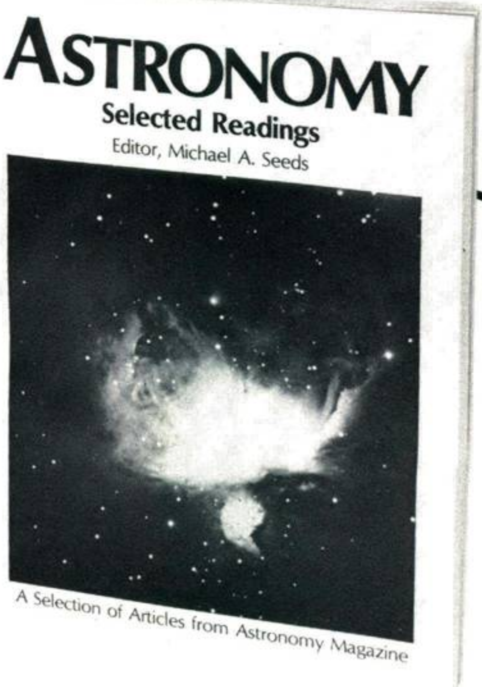

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astronauts, not seismometers, to "experience" them?

As to the magnetism in the rocks (which, to Velikovsky's credit, was a surprise to everybody else), his exact words were that the Moon's surface "could conceivably be rich in remnant magnetism resulting from strong currents when in the embrace of exogenous magnetic fields." Such a careful wording would have been safe if magnetism had not been found, but Velikovsky hit the jackpot here. Or did he?

The actual nature of the lunar remnant magnetism is stranger than Velikovsky predicted. Far from being a planetwide field, it is locally "patchy" and varies in orientation and strength. However, the fossil magnetic fields appear related to random impact events, not to the simultaneous imprinting of an outside field. The lack of homogeneity has led moon geologists to reject exterior causes such as the one Velikovsky predicted.

Nor is the timing in agreement. Velikovsky wrote: "I maintain that less than 3,000 years ago the Moon's surface was repeatedly molten and its surface bubbled," causing most lunar craters. Other craters and the lunar rilles were supposedly created by interplanetary lightning discharges. Radioactive dating indicates that the last melting took place *billions* of years ago, but Velikovsky has found fault with it.

Additionally, in 1967, Velikovsky warned of danger to the lives of the astronauts. He claimed to have identified "a special condition the astronauts most certainly will meet on the Moon that may...endanger the lives of the astronauts even if they succeed in returning...." "Radioactivity must still be present on the surface of the Moon...far exceeding any exposure regarded as safe." Especially near the rayed craters he forecast "a strong, decidedly harmful, radioactivity." But it wasn't there: Apollo instruments measured no radioactivity more intense than that from terrestrial basalt — and the astronauts returned safely.

Regarding the composition of the lunar surface, Velikovsky was quite specific. In a letter to the National Academy of Sciences on July 2, 1969, he claimed that moon rocks "will be found rich in oxygen, chlorine, sulfur, and iron." Actually, iron was found to be present at or slightly below the average solar abundance, and both chlorine and sulfur were depleted by several orders of magnitude. Oxygen, while present in great absolute amounts, was far from rich in terms of solar system averages. In fact, since iron was found to exist primarily in the ferric rather than ferrous (or more highly oxidized) forms, geologists deduced that lunar rocks were formed in the presence of amounts of oxygen many orders of magnitude less than on Earth.

Velikovsky also predicted "carbides, into which hydrocarbons would transform when heated, in substantial quantities..." and there were none. Additionally, he had said that "the Moon may well have hydrocarbons in the form of dried naphtha, bituminous rocks, asphalt, or waxes." And again his prediction was wrong.

"The most despicable of all ways of suppression is denying me the originality and correctness of my predictions."

"In my understanding," Velikovsky wrote in the *New York Times* during the Apollo 11 landing, "less than 10,000 years ago, together with the Earth, the Moon went through a cosmic cloud of water (the Deluge) and subsequently was covered for several centuries by water...." Yet moon rocks show no trace of such oceans.

One of the cornerstones in the edifice of the "successful" Velikovskian predictions is the heat of Venus. When he wrote *Worlds in Collision*, the scientific world supposed Venus' surface temperature only slightly hotter than Earth's. Yet space probes later found that the temperatures exceeded 800° F, a figure which seemed to bear out Velikovsky's claim that the newborn planet had at one time been "candescent," or glowing, with excess heat.

Astronomers attribute the high temperature of Venus to the "runaway greenhouse effect" which Velikovsky has denounced as clumsy groping. "Completely unsupportable," he called it in 1974, adding that such an idea was "in violation of the Second Law of Thermodynamics."

But the heart of Velikovsky's prediction was not so much the temperature, but that Venus would be giving off more heat than it received from the Sun, and therefore still be cooling off. The greenhouse effect postulates a planet in thermal equilibrium at high temperature. Space probes and recent terrestrial measurements have both provided voluminous evidence that the planet is not cooling. Among the remaining theories still competing to account for the high surface temperature, the "runaway greenhouse effect" is still very much in the running. But Velikovsky's key claim is wrong.

Velikovsky also claimed that "the presence of hydrocarbon gases and dust in the cloud envelope of Venus would constitute a crucial test..." and further that "on the basis of this research, I assume that Venus must be rich in petroleum gases." Neither the Russian nor the American atmospheric probes detected these materials.

Radar scans from the Pioneer-Venus probe laid to rest another prediction: the surface of Venus being very plastic, specifically, with "mountain-high ground tides." And while he claimed to have predicted the massive atmosphere of Venus, there is no written record showing that he made such a prediction until after it was discovered. Lastly, he claimed that Venus would have "a weak magnetic field," an ambiguous stab that comes up against Pioneer-Venus measurements. But what did he mean by "weak"? There is no detectable intrinsic venusian magnetic field at all, only the magnetic fields induced by the solar wind, which he did not predict.

The planet Mars played an important role in Velikovsky's reconstruction of ancient history, since in his model it is the agent responsible for a series of worldwide catastrophes in the eighth and seventh centuries B.C. He expected the planet to have suffered equally or more than Earth, and asserted it would be covered with fractures — the Martian "canals." In 1974 he reported: "The '*canali*' proved to be...rifts caused by twisting of strata." But the canals were optical illusions; and the valleys and chasms on Mars, however mysterious their origin remains, do not appear to be the result of "twisting strata" within the last 3000 years. Missing, too, were the localized areas of strong radioactivity which Velikovsky had expected.

"I claimed that neon and argon are chief constituents in the martian atmosphere," he reminded scientists in 1969, pointing to a passage in *Worlds in Collision*. In 1973, when some highly confused readings from a Soviet Mars probe hinted at argon compositions as high as thirty percent, Velikovsky at once saw himself as vindicated. The celebration, however, was premature, because in 1976, the

6
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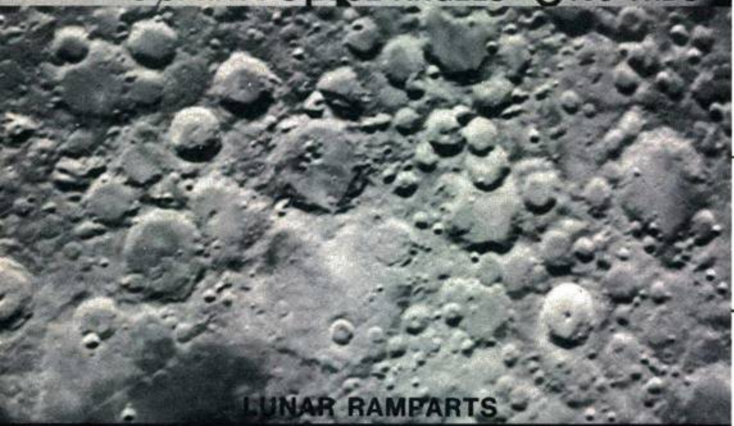

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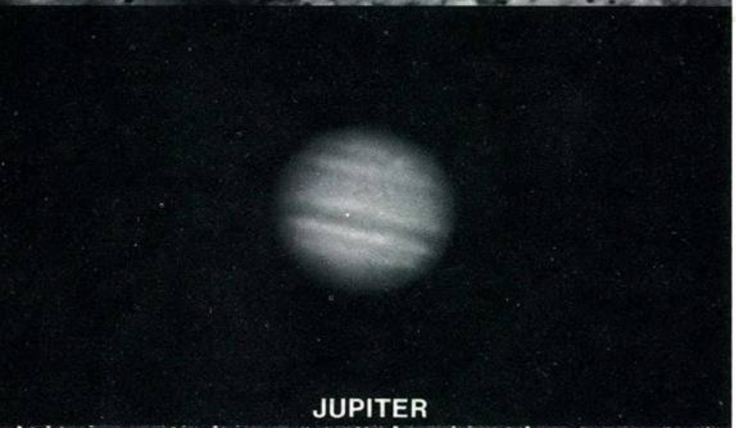

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Tube Weight	4¼#
Telescope Weight	13#
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Carrying Case Dimensions	9" x 12" x 24"
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Viking probes determined that argon only made up one to two percent of the martian atmosphere — far below Velikovsky's predictions.

His followers sought to rationalize this discrepancy. Writing in *The Age of Velikovsky*, physicist C. J. Ransom claimed that "it is not now known if this is the average percentage...or if the Soviet measurements are correct and this is one of the depleted areas," a depletion allegedly caused by the selective concentration of argon in other regions (the argon is hiding!). Writing in the pro-Velikovsky journal *Kronos* in 1977, the then editor-in-chief, Lewis M. Greenberg, made the excuse that "the relatively low amount might be the result of an argon loss to the Earth, the Moon, and interplanetary space during the celestial events described in *Worlds in Collision* (the argon was kidnapped!). Another leading Velikovsky disciple, Ralph E. Juergens, asserted that the phrase "in rich amounts" must be reinterpreted in relation to the Earth, where argon makes up about one percent of the atmosphere, thus leading to the conclusion that martian argon may be up to twice as plentiful in its relative concentration (or: Velikovsky was right, but misinterpreted his own words!).

Prior to the Viking landings, Velikovsky predicted that Mars would have a "neon rich" atmosphere, and had criticized NASA for anticipating "in my opinion, too little — 666 parts per million — neon...The logic that led me to these conclusions was the same that made me make similar advance claims concerning the Moon." When Viking landed, it found that the neon concentration was on the order of ten parts per million — almost a hundred times less than Velikovsky's "too little."

And Viking had other surprises for Velikovsky. The martian polar caps had been the subject of explicit predictions by Velikovsky: "Chances are that they are composed of the same organic molecules as the envelope of Venus," he wrote in 1963, clarifying his earlier prediction that they were "probably in the nature of carbon" as carbohydrates of the type which had been called "manna" when it had fallen to Earth in 3500 B.C. to nourish the Israelites. The prediction, in other words, was that the martian polar caps would be edible and nutritious. Mariner and Viking data took a long time to confirm that the caps contain water ice and frozen carbon dioxide (dry ice), but there is no evidence for heavier organic compounds.

Regarding the possibility of biological activity, he had told an audience in 1974 that "...it is not excluded that Mars is richly populated by microorganisms pathogenic to man...I do not discount the probability that the seasonal changes in the color of the martian surface may be due to seasonal microbial or other low vegetable activity." Although this is very weak for a "prediction," the pattern of Velikovsky's responses is such that any discovery of life would have been seen as confirmation of another prediction, while the failure to discover life would not disprove the "prediction."

Jupiter is the source of the birth of Venus and other comets in the Velikovskian cosmology, and the Red Spot "an atmospheric effect related to the scar where Venus was ejected." But there is no surface to scar, and the Red Spot is now thought to be a stable hurricane which floats freely in the turbulent atmosphere.

Velikovsky's followers are very proud of his prediction of radio noises from Jupiter — which really are there. He made the prediction in a speech given at Princeton on October 14, 1953: "The planet Jupiter is cold, yet its gases are in motion. It appears probable to me that it sends out radio noises as do the Sun and the stars."

Velikovsky was wrong about the temperature of Jupiter, as were most of the scientific community. The radio noise which Velikovsky predicted, called "thermal" because it is emitted by any object warmer than absolute zero, comes from Jupiter and the other planets as well.

But the dominant radio noises from Jupiter are the decimetric (caused by electrons oscillating in the atmosphere) and the decametric (caused by electrical discharges in the upper atmosphere), and both are far more powerful than the thermal radio noises — Velikovsky's prediction does not point to them. At best, his "hit" is a glancing one here, and is not nearly as impressive as later accounts made it sound.

"My Worlds in Collision **...does not require any revisions...whereas all books on terrestrial and celestial sciences of 1950 need complete rewriting."**

Regarding Saturn, Velikovsky claimed that it had once been the largest planet in the solar system and had constituted a double-planet with Jupiter; Saturn subsequently exploded, showering the solar system with water which accounted for the Deluge on Earth. "It is conceivable," Velikovsky wrote, "that the Earth was, at that time, a satellite of Saturn, afterwards possibly becoming a satellite of Jupiter." The Saturn shower brought Earth most of the components of seawater salt: "Chlorine may thus be of extraneous origin," he hypothesized. "It could possibly be present in some different combination on Saturn." Also present on Saturn, according to a suggestion made by Velikovsky at NASA's Ames Research Center in August 1972, is "primitive plant life."

The record, if it proves anything, demonstrates that Velikovsky's chief skill has been in making flexible predictions, and reinterpreting them skillfully in light of later discoveries. "How could I produce this score of correct prognostications?" he asked in 1974, answering the rhetorical question with the circular assertion that he had been correct from the very beginning.

While space scientists objected to this mode of creating "correct" predictions, Velikovsky refused to listen to criticism: "The most despicable of all ways of suppression is denying me the originality and correctness of my predictions."

The pro-Velikovskian Italian mathematician, de Finetti, called scientists a "despotic and irresponsible Mafia," their criticisms "chiefly remarkable for dishonesty and incompetence." The level of debate on this issue, obviously, has not been conducive to rationalism and dispassionate consideration of the evidence.

But the bottom line was Velikovsky's unwillingness to bend in the slightest, or to admit (as in the case of the argon on Mars) that he might have been wrong in anything. "My *Worlds in Collision*...does not require any revisions," he told the San Francisco symposium in 1974, "whereas all books on terrestrial and celestial sciences of 1950 need complete rewriting."

But science is flexible, and does grow and change. Revision, in the face of evidence, is the key to further understanding. That comment, more than any other, may demonstrate that, far from advancing into the space age with the onward march of science, Velikovsky's theories remain frozen in a universe littered with theories long since abandoned as obsolete.

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eye
on the
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introducing the summer stars

the wanderers

In the evening sky last month, all five of the naked-eye planets were arrayed. This month, the count has dropped to only three: Mars, Jupiter, and Saturn.

The appearance these three have made each evening over the last six months is drawing to a close as the Sun approaches that part of the sky in which we see them.

Why? If you watch carefully from night to night over a week, say, you'll notice that any given star or constellation sets a bit earlier each night (three minutes fifty-six seconds earlier, to be fussily precise).

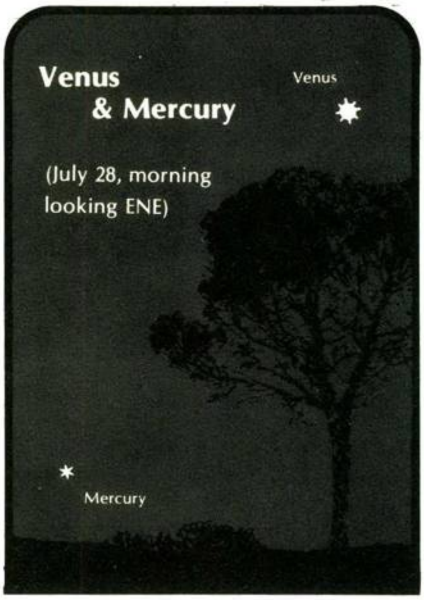
Over the course of a month, this four minute daily increment adds up to a full two hours — which is why your Star Dome map shows the sky at one time at the beginning of the month and two hours earlier at its end. It also explains why the constellations shift across the sky as the year rolls by.

But of course the planets aren't like stars: they move, and because they do, you can't rely on a simple seasonal progression bringing them into view at set times of the year. Mercury, Venus, and Mars circle the Sun at speeds not too disparate from Earth's; therefore they spend a lot of time overtaking and being overtaken in our everlasting chase around the Sun. Their celestial coordinates are constantly changing as they sweep by in front of the starry backdrop.

But on the other hand, the planets from Jupiter outward are so distant and slow-moving that they don't bestir themselves *much during* any particular yearly apparition. Because they usually remain relatively fixed in one temporary "host constellation" each year, they're regularly engulfed by a blitz of sunlight every 12 or 13 months. During July and August we'll be seeing this happen to two of them.

As darkness arrives at the end of twilight in July, **Jupiter** is the bright white object you see low in the west; **Saturn** is a dimmer point of light, yellow-white in color, between Leo and Virgo (compare the sky with the Star Dome); and **Mars** is the orange dot about as bright as Saturn that's in the western part of Virgo.

In the south-central part of the constellation Leo and setting now about two hours after the Sun, Jupiter will fade into the bright twilight sky next month, not re-emerging until late in September when you'll find it low in the east before sunrise.



The first half of July is probably your last chance to get a good look at it. Remember that Leo counts as a spring constellation and is now departing the scene.

Saturn trails along not very far behind Jupiter (it sets 2½ hours after the Sun) and will likewise be caught by the advancing twilight, late in August. Similarly, you'll find it reappearing in the morning sky in October. For Saturn, too, don't pass up whatever opportunities come along now for watching it.

Mars won't be caught by the Sun so easily. It'll cross the western half of Virgo during July, seeming to outrun the encroaching Sun in a chase toward Spica, the constellation's first-magnitude luminary. Being farther to the east than Jupiter or Saturn, Mars sets three hours after the Sun does.

What happened to those other two we found and followed last month? You'll have to get up early (or wait up all night) if you want to see the inner planets, Venus and Mercury. Venus swung into the morning sky last month, popping up over the eastern horizon late in June; Mercury won't arrive to accompany it there until the last week of July.

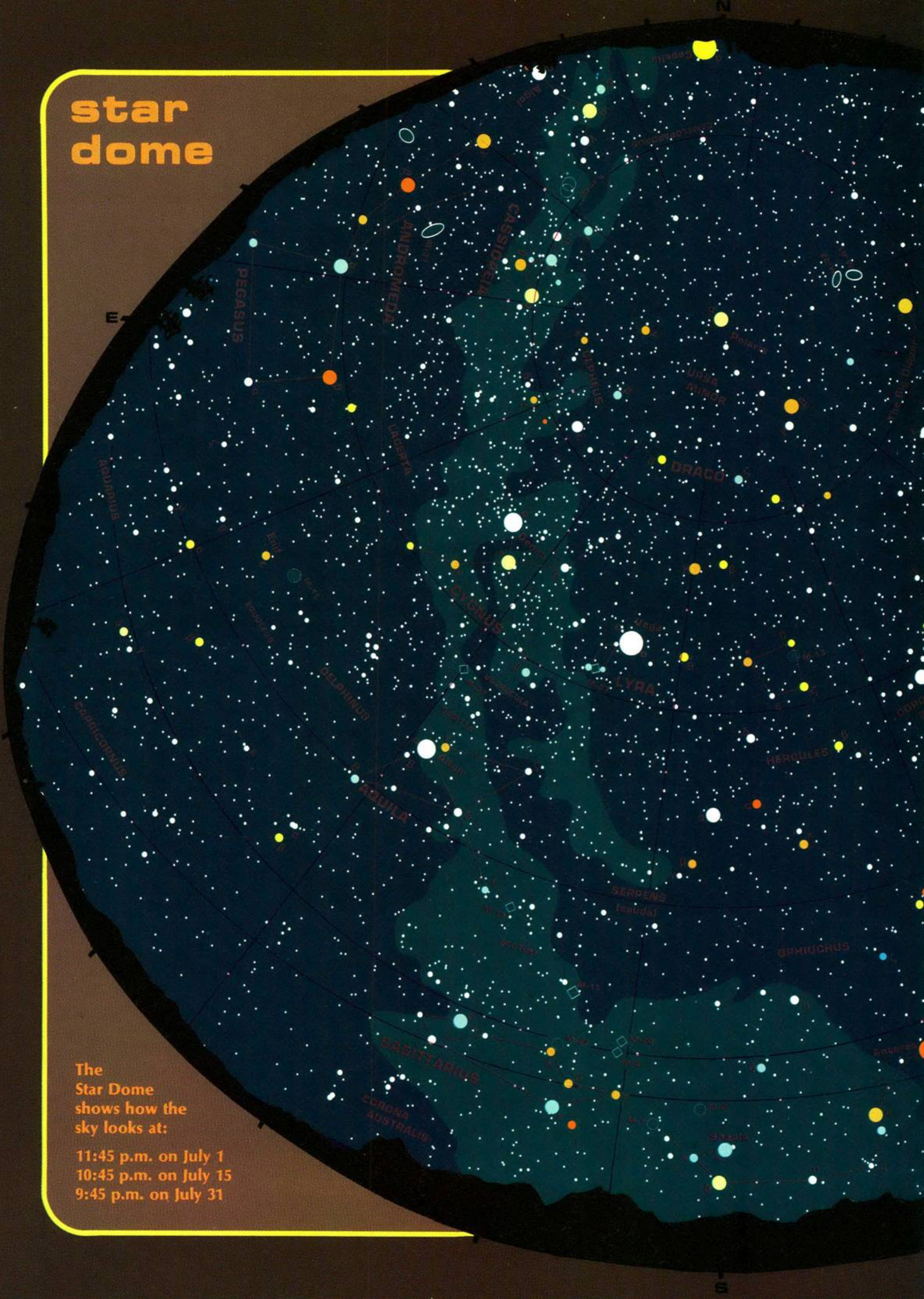
Venus will be rising about 2½ hours before the Sun does; look for it as a very bright object moderately low in the east. During July its day-to-day motion (moving higher and a little southward) will be pretty rapid, so if you don't get a good look at it one day, try again a morning or two later. On the morning of the 22nd (and a few days before and after), it'll be especially bright.

Mercury passes between the Earth and Sun on the 11th (inferior conjunction), switching from the evening sky into the morning one. It never strays far from the solar orb, so despite its rapid motion, you won't catch sight of it until July 24th or so.

Go outside about 45 minutes before sunrise and look very low in the east-northeast, to the left of Venus and far

Above: The triangle of Mars, Jupiter, and Regulus held the attention of many skywatchers this spring. Early in May they were at their closest (photo by Roger Sad). Below: David Hearn's star-trail photo was very easy to make: a 50 mm f/2.8 lens, Ektachrome 400 (pushed to 800 ASA), and a 15 minute exposure.

star dome


N
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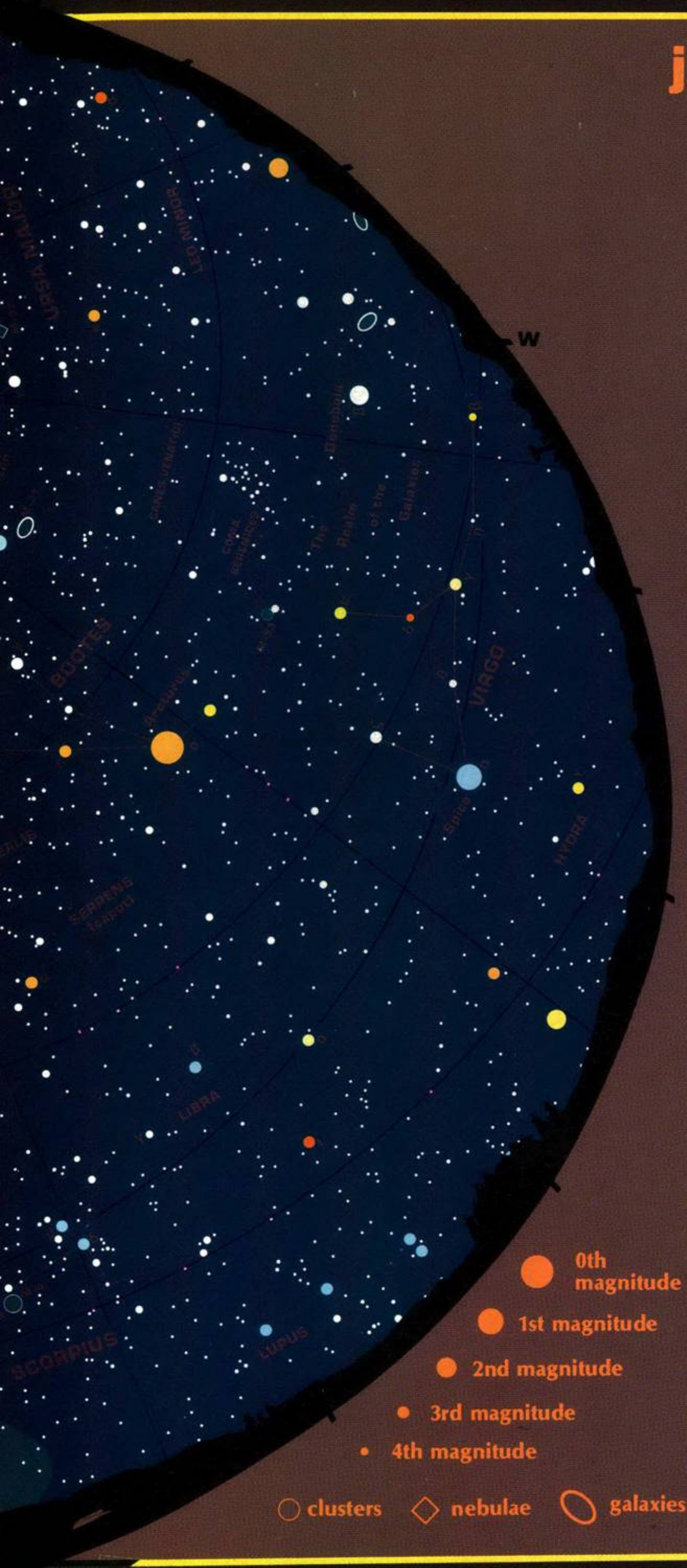
CYGNUS
Deneb
Vega
LYRA
DELPHINUS
CAPRICORNUS
AQUILA
Altair
SAGITTA
VULPECULA
HERCULES
SERPENS
(cauda)
SCUTUM
OPHIUCHUS
SAGITTARIUS
CORONA AUSTRALIS

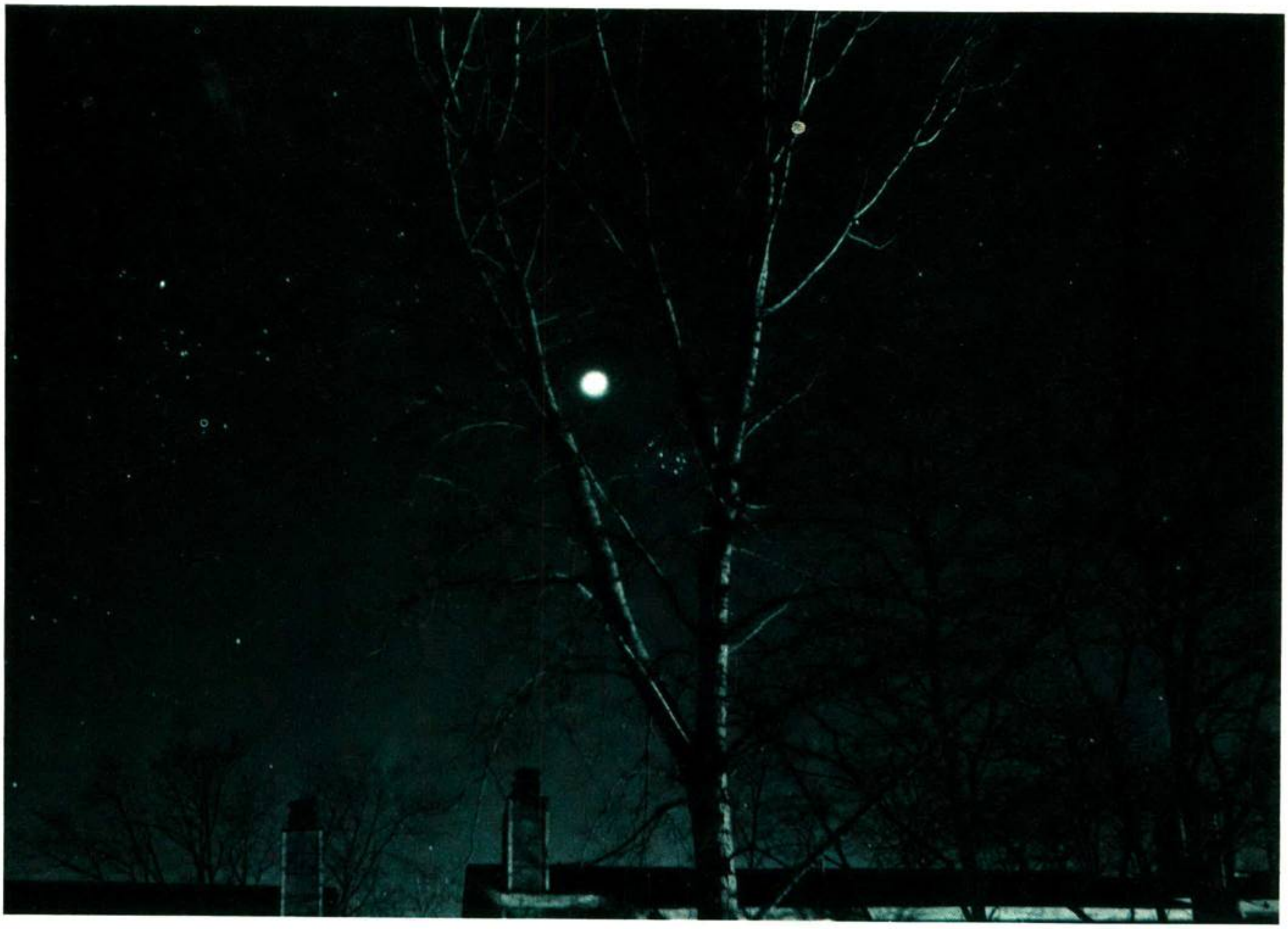
The Star Dome shows how the sky looks at:

11:45 p.m. on July 1
10:45 p.m. on July 15
9:45 p.m. on July 31


URSA MAJOR
LEO MINOR
W
Denebola
CANES VENATICI
COMA BERENICES
The Realm of the Galaxies
BOOTES
Arcturus
VIRGO
Spica
HYDRA
SERPENS (CAPUT)
LIBRA
SCORPIUS
LUPUS
0th magnitude
1st magnitude
2nd magnitude
3rd magnitude
4th magnitude
clusters
nebulae
galaxies

july sky almanac

4th	The Moon is at perigee (closest to the Earth) at noon EDT: 229,161 miles.
5th	Last quarter moon today (3:27 a.m. EDT); look for it in the western sky on your way to work in the morning. Also, the Earth is at aphelion, its farthest distance from the Sun: 94,303,000 miles.
6th	Between now and about the 20th is your best opportunity (the "dark of the Moon") for observing under really dark skies.
11th	Mercury passes between the Earth and Sun, out of the evening sky into the morning. About two weeks from now, try looking for it very low in the east before sunrise.
12th	The Moon is new at 2:46 a.m. EDT.
15th	Jupiter gets occulted (temporarily covered up) by the Moon this evening — in most areas west of the Mississippi.
18th	The Moon is at apogee (farthest from Earth) this evening: 250,698 miles.
20th	First quarter moon comes at 1:51 a.m. EDT today.
21st	Venus reaches its greatest brilliancy in the morning sky: –4.2 magnitude. Only the Sun and Moon are brighter.
24th	Start looking for Mercury in the predawn skies.
27th	The Moon will be full in the early afternoon (2:54 p.m. EDT).



Early in April, Venus passed close by the Pleiades star cluster. Here you see the planet (bright and overexposed) between the Pleiades on the right and the more spread-out Hyades to the left. Phillip Niles used Tri-X and a 15 second exposure at f/2.2 with a 55 mm normal lens. His camera was tripod-mounted.

below. Its brightness will fall about midway between that of Jupiter and Mars (or Saturn) in the evening. At first, some people find using binoculars helpful in locating Mercury — switching back to naked eye when they know just where to look.

the starry sky

Formed by the brilliant stars **Vega**, **Altair**, and **Deneb**, the **Summer Triangle** clearly marks July night skies. Already approaching the zenith as twilight ends and riding high overhead as the night progresses, this distinctive formation also spans one of the more interesting stretches of the Milky Way.

It's easy to find the Summer Triangle on July evenings. First look for a particularly brilliant white star nearly directly overhead well after the end of twilight — around 10 to 11 p.m. This is **Vega**, the brightest star in the compact constellation **Lyra** (the lyre). Then look down toward the eastern horizon for the second star in the Triangle, **Deneb**. The third — **Altair** — is about an equal distance from the first two down toward the southeast.

Now look for the **Northern Cross** framed within the Summer Triangle. This well-known asterism is formed by six stars in the shape of a cross with Deneb at the top. The Northern Cross is actually part of the constellation **Cygnus** (the swan), with the crossbar representing the swan's wings, Deneb its tail, and the bottom of the "upright" beam of the cross the long neck and head of the swan.

Cygnus seems to be flying along the Milky Way, for its length defines the direction of the heavenly river across the summer sky. There is another bird here as well, also flying along the Milky Way just below the swan — **Aquila** the eagle. Aquila is marked by Altair, the third of the three stars making up the Summer Triangle.

The **Great Rift** splits the Milky Way in this region. Beginning at Deneb, the soft glow of the celestial stream divides in two, following parallel courses down through Aquila toward the southern horizon until finally the westernmost tributary (to the right) peters out just before reaching the constellation **Ophiuchus**. We know now that this dark rift through the Milky Way is not a real split within the disk of our Galaxy, but is actually caused by a gigantic cloud of obscuring dust lying between us and more distant stars.

Follow the Milky Way down to the southern horizon, and you will find an even more exciting region, both because of its richness and brilliance and also because of what we know about it. Here we find the thick, crowded star clouds of Scutum and Sagittarius. **Sagittarius** (the archer) is easily identifiable just above the southern horizon because of its distinctive teapot shape. To the left (east) is the handle, and to the right (west) a single star seems to mark the spout from which pours the great shining clouds of the Milky Way.

As you gaze at Sagittarius, remember that here you are looking in the direction of the center of our Galaxy. But despite the rich brilliance of this part of the Milky Way, you are not really looking at the galactic core itself. The core is hidden from our view by huge intervening clouds of gas and dust. Still, the view here is the most dramatic along the entire length of the Milky Way.

Now look just to the right of Sagittarius, and you will find a curving line of stars topped by three stars at a right angle to the others. This is the constellation **Scorpius** (not Scorpio which is an astrological sign, not a constellation). Scorpius is one of the few constellations which actually looks like its namesake, the scorpion. The curving line of stars clearly resembles the upturned tail of a scorpion prepared to sting, while the three stars at the top mark its claws. The second-magnitude star at the very end of the tail in fact has the name "scorpion's sting" — in Arabic, **Shaula**. The brilliant orange-red star just behind the "claws" is **Antares**, a red giant whose naked-eye resemblance to the planet Mars gave it its name (Ant-Ares: "Not-Mars"). Once you've learned the constellations, though, you'll never find yourself fooled by Antares!

Now let's move back to the zenith, the point directly overhead where we found Vega. Just to the west of Vega is the constellation **Hercules**, marked by the **Keystone**, a quadrilateral of four stars. A little farther down toward the western horizon is the curving crown of **Corona Borealis**, distinguished by the glittering star **Alphecca**, seemingly set into the crown like a precious stone. Next we come to **Bootes**, with brilliant **Arcturus** at its base, our friend during the spring and early summer but now sinking rapidly toward the western horizon after sunset.

Rising just north of east on July evenings you can see another famous quadrilateral of stars like the Keystone in Hercules, but this time much larger. This is the **Great Square of Pegasus**, the flying horse. All four of these stars have beautiful, exotic names which are fun to learn. The highest of the four above the horizon on July evenings is **Scheat**, and the lowest is called **Algenib**. The other two corners of the Great Square are marked by **Markab** on the right and **Alpheratz** on the left.

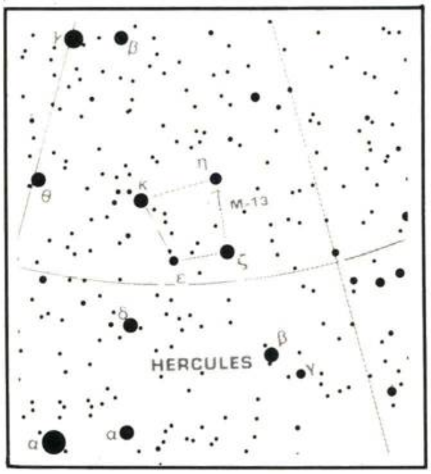
On July evenings the Great Square of Pegasus looks rather more like a diamond than a square, for it is rotated 45° relative to the eastern horizon. Perhaps this is appropriate, though, considering the great popularity of a *particular* sport during this time of year.

skylore

The constellation Hercules is one of the most ancient of all stellar figures, even older than the mythic figure whose name it now bears. The association with the great hero of ancient Greece was never clearly made by the Greeks themselves, who more often saw here an unknown kneeling figure.

But if the Greeks were not sure about the heavenly figure, they were at any rate quite familiar with the Hercules of myth and legend. Hercules, or *Heracles* as he was called in Greek, was a great and honored hero — a sort of superman — who eventually became a god himself. As befits such a person, he had divine parentage: Zeus, the ruler of the gods, was his father. His mother was one of those many women whom Zeus seduced, always to the distress of his goddess wife Hera. Unlike the others, though, there must have been something special about Hercules' mother Alcmene, for Zeus arranged a triple night in which to sport with her. He ordered Helios, the god of the Sun, to stay at home the following day instead of riding his chariot across the sky. In addition, the Moon was made to move slowly, while all mankind was cast into an unnaturally long slumber so that the time would not be missed.

We can suppose that Alcmene — who, it must be said, believed Zeus to be her rightful husband — was somehow kept so busy that she did not notice the extraordinarily long night either. Of course when her true husband returned the next normal night, he found her mysteriously tired, and not at all "in the mood." He wisely consulted an oracle before he let his suspicions carry him away, though, and upon learning who cuckolded him, even more wisely refrained from taking any action. In fact, he never again dared to sleep with Alcmene at all, lest Zeus become jealous. The legend does not report what Alcmene's reaction to all this was.



In a feeble attempt to placate the wrath of Hera (for Zeus had great plans for his hero offspring) he named Alcmene's son after her: Heracles, which means "The Glory of Hera." Apparently this only angered Hera more, because she went on to devote all her attention to making Hercules' life as difficult and miserable as possible. Of course if she hadn't, Hercules wouldn't have had such great deeds to his credit, for he managed to handle all the snakes, monsters, dragons, and other little difficulties Hera tossed him. In the end, he was felled not by ordinary means, but by occult power.

Most famous among the exploits of Hercules were his renowned Twelve Labors (or Labours, as the British insist on calling them). These Labors may in fact be astronomical in origin, and far more ancient than the myth of Hercules.

For the primitive version of the story, we have to go several thousand years farther back into the past, and take a look at the old Babylonian epic of Gilgamesh. This epic, which is more than five thousand years old, relates the adventures of the sun-god as he moves through the twelve zodiacal signs. Each sign, and therefore each month, had a particular adventure associated with it. Thus it may be that the Greeks changed the solar hero Gilgamesh into the semi-divine hero Hercules, and his Twelve Labors were therefore derived from the adventures of Gilgamesh.

Another incident in Hercules' life is definitely astronomical. It seems that Alcmene, justifiably nervous about Hera's displeasure, attempted to expose Hercules after his birth. ("Exposure," or abandonment on a hillside, was the Greeks' method of infanticide, a means of disposing of unwanted children.) But Zeus got Athena to take Hera to the spot, where Athena pretended surprise at finding such a robust baby left to die. Hera, not knowing who the child was, was moved by pity and attempted to nurse him. Unfortunately, Hercules chose this moment to manifest for the first time his great strength, and sucked so hard that Hera cast him down in pain. The milk thus spilt became — you guessed it — the Milky Way.

Hercules was then returned to Alcmene by Athena with a warning to guard him well, for he had the favor of Zeus if not that of Hera. And because he had tasted of the divine Hera's milk, Hercules was now immortal, and Zeus prophesied that "No living man may ever kill Hercules, but a dead enemy shall be his bane."

Such was indeed the case, for Hercules was ensnared by the magic of the centaur Nessus, whom he had slain. Before he died, Nessus tricked Hercules' wife into giving him a cloak whose cloth, soaked with a potion provided by Nessus, clung to his flesh and burned it horribly. The only escape seemed to be suicide, but when Hercules attempted to cast himself onto his funeral pyre, his father Zeus bore him up to heaven in his chariot where he became a god. Hera even went so far as to adopt Hercules, and forgiving him, loved him greatly. So the story of the greatest hero of ancient Greece ended happily after all.

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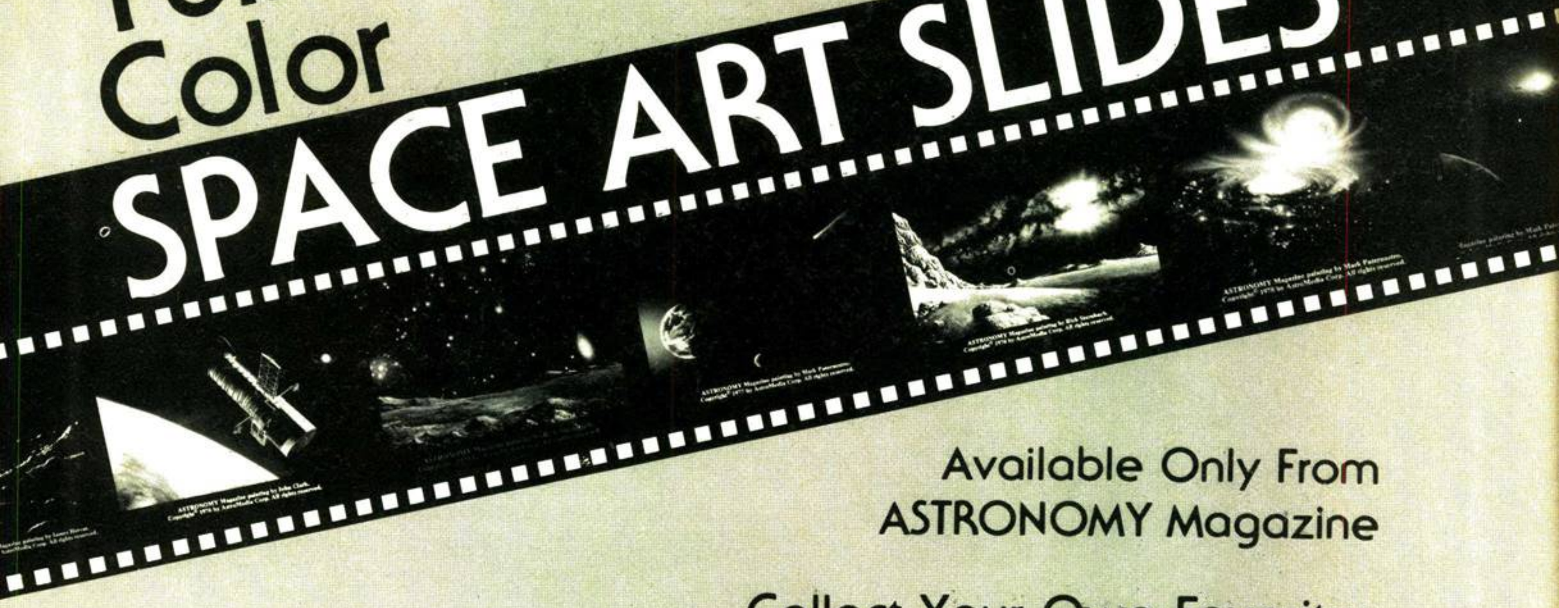

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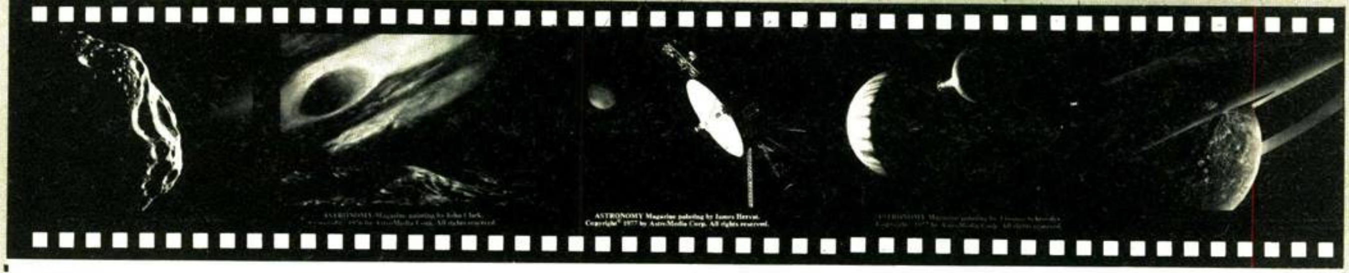
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- ☐ AS-01 Uranus' Rings July 1977, cover
- ☐ AS-02 Martian Duststorm March 1977, pp. 36 & 37
- ☐ AS-03 Solar Chromosphere September 1977, p. 35
- ☐ AS-04 Triple Star System September 1977, p. 12
- ☐ AS-05 Asteroid Belt September 1977, pp. 6 & 7
- ☐ AS-06 In The Beginning January 1976, pp. 6 & 7
- ☐ AS-07 Vallis Marineris January 1977, pp. 12 & 13
- ☐ AS-08 Spiral Galaxy April 1976, p. 19
- ☐ AS-09 Colliding Galaxies April 1976, p. 22
- ☐ AS-10 Asteroid Eros June 1976, pp. 6 & 7
- ☐ AS-11 Venus Probe August 1976, cover
- ☐ AS-12 Red Giant December 1976, p. 27
- ☐ AS-13 Radio Galaxy Core November 1976, p. 22
- ☐ AS-14 Supernova Explosion September 1975, p. 52
- ☐ AS-15 Saturn From Above January 1975, p. 30

Thomas Schroeder
- ☐ TS-01 Enzmann Starships August 1977, pp. 6 & 7
- ☐ TS-02 Light Sail April 1978, pp. 6 & 7

Rick Sternbach
- ☐ RS-01 Exploding Galaxy May 1976, pp. 12 & 13
- ☐ RS-02 Cosmic Gas Cloud May 1976, p. 30
- ☐ RS-03 Erupting Quasar May 1976, pp. 6 & 7
- ☐ RS-04 View From Distant Planet December 1975, pp. 12 & 13

Mark Paternostro
- ☐ MP-01 Tharsis Eruption October 1977, pp. 20 & 21
- ☐ MP-02 Terraformed Moon May 1978, cover
- ☐ MP-03 Brown Dwarf April 1978, pp. 20 & 21
- ☐ MP-04 Swarms of Stars March 1978, pp. 6 & 7
- ☐ MP-05 Matter vs. Antimatter March 1978, pp. 20 & 21
- ☐ MP-06 Formation of Gas Giant December 1977, pp. 6 & 7
- ☐ MP-07 Collision Course With A Comet December 1977, pp. 20 & 21
- ☐ MP-08 Solar Polar Probe August 1977, p. 19
- ☐ MP-09 Black Hole February 1977, p. 27
- ☐ MP-10 Black Hole, Asteroid Collision February 1977, cover

James Hervat
- ☐ JH-01 Pluto February 1977, pp. 20 & 21
- ☐ JH-02 Uranus From Voyager February 1977, pp. 6 & 7
- ☐ JH-03 Formation of Mare Imbrium September 1976, pp. 6 & 7

Anne Norcia
- ☐ AN-01 Mercury Terraformed May 1978, pp. 20 & 21
- ☐ AN-02 Red Dwarf Explosion July 1978, cover

John Clark
- ☐ JC-01 Jupiter From Io February 1976, pp. 6 & 7
- ☐ JC-02 Space Telescope November 1976, pp. 6 & 7
- ☐ JC-03 Starship To Antares August 1974, p. 4 & 5
- ☐ JC-04 Starship To Zeta Reticuli December 1974, p. 4 & 5

David Egge
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photography
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stalking the gaseous nebulae

Among the most attractive subjects for astrophotography are those vast, wispy entities strewn along the Milky Way: the gaseous nebulae. Superb targets for wide fields of view, they almost tempt you into believing that Schmidt cameras were invented for the sole purpose of taking their picture. Even the very simplest equipment, the venerable piggyback-mounted camera with a fast 50 to 135 mm lens will give you splendid photos.

But success won't come if you just load up with Tri-X, piggyback your camera on the telescope, and fire away. As anyone who's tried can tell you, few objects are more difficult to capture impressively on film. Why? Let's take a short detour into astrophysics and see just what it is we're trying to photograph.

Gaseous nebulae, as their name suggests, are simply that: giant clouds of gas (mostly hydrogen) which inhabit a volume of space anywhere from a few light-years in diameter up to hundreds of light-years across. Cold gas is invisible by itself; we can only tell it's present if it glows (or obscures some more distant luminous object).

The way to get a cloud of gas to light up is to inject it with a lot of energy. This usually comes from hot, young stars embedded within it (gaseous nebulae are the main places where gas and dust combine to coalesce into stars).

When hydrogen — the chief component — is bombarded with energy, it radiates light. But the nature of its light is *very different* from that of a star.

Stars radiate light of all colors (though the star's temperature will determine which color dominates); their spectra are *continuous*. Hydrogen, on the other hand, radiates only at certain wavelengths (colors); physicists call this a *discrete*, or *line*, spectrum.

The strongest color found in gaseous nebulae (therefore the best color to photograph them in) is the hydrogen-alpha (H-α) line at 6563 Angstroms in the red region of the spectrum. Then why don't they look red through a telescope?

H-α isn't the only spectral line they produce: H-β (another hydrogen line) and a strong emission line due to oxygen, both lying in the blue-green part of the spectrum, also contribute their light. Your vision is more sensitive to these colors than to red and so the nebulae look bluish-green.

Which Film Should I Use?

Ordinary (panchromatic) emulsions suffice to record nebulae in a so-so way. But their color sensitivity usually doesn't extend far enough into the red part of the spectrum to pick up all the H-α that's there. And they also respond to airglow and urban light pollution.

Airglow, a naturally occurring source of light pollution, is always present and radiates at some wavelengths that are uncomfortably close to the nebular lines (6300 A and 6360 A). Light pollution from outdoor lighting (streetlights, mainly) lies in the blue and yellow part of the spectrum and thus won't interfere if you confine your attention to the region of H-α. However, high-pressure sodium lights, becoming more and more common, do radiate down into the red and may cause problems.

The trick lies in getting a film/filter combination that admits as much H-α as possible, but cuts off the neighboring red airglow lines as well as any residual sodium streetlight pollution.

Despite all the constraints, it isn't as impossible as it sounds: Kodak makes astronomically-oriented films (the 103a series) that have fairly precise spectral sensitivities when combined with filters.

These are fast and relatively coarse-grained films, being designed for long exposures on faint subjects. The three to know about are 103a-O (blue-sensitive), and 103a-E and 103a-F (both blue and red-sensitive). The F emulsion differs from the E in that F's sensitivity extends farther into the red.

For the astrophotographer intent on gaseous nebulae, either 103a-E or F seems like a good choice, but closer examination reveals that 103a-E is better. The extended red-sensitivity of the F emulsion works against you because on the long-wavelength (redder) side of H-α are some other airglow lines to be avoided; 103a-E doesn't "see" them.

Kodak supplies these films only in bulk, and since few everyday photographers have a need for them (and they are difficult to store), your local camera store won't stock them. A number of astronomical equipment dealers buy in bulk and re-spool individual rolls — check the ads in recent issues.

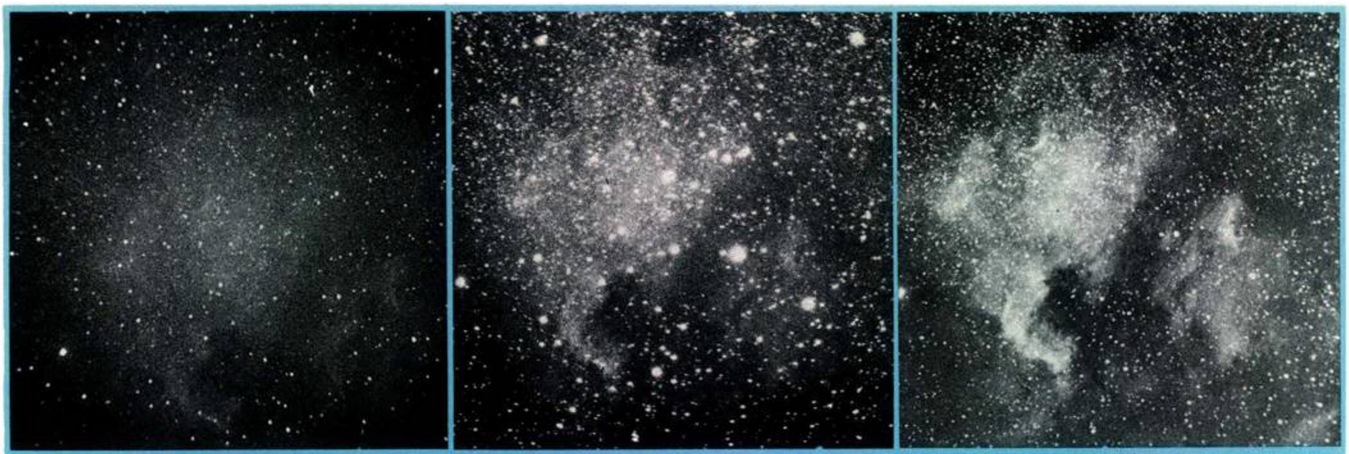
Which Filter Should I Use?

To isolate the H-α nebular light, 103a-E must be combined with a filter. It won't surprise you to learn there are several choices available, all having trade-offs in efficiency versus cost.

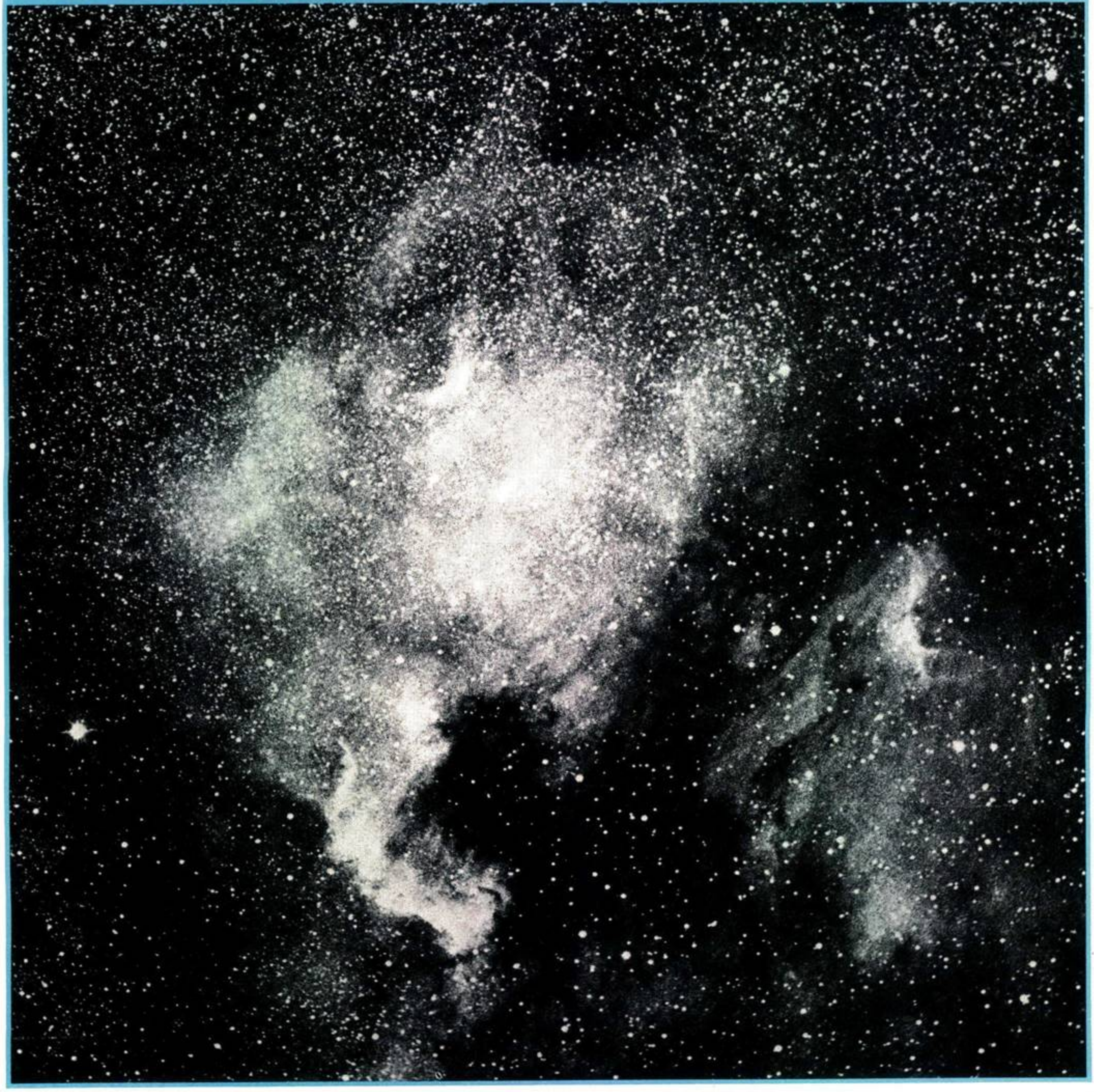
At the simple end, Kodak makes two filters which cut off 103a-E's residual blue sensitivity: Wratten #s 29 and 92. Both are deep red, but the #92 stops twice as much airglow light (at 6300 A and 6360 A) as the #29. (It also cuts down the amount of H-α transmitted by about 15%.) On the long-wavelength side of H-α, both filters use the natural sensitivity fall-off of the emulsion to truncate its response.

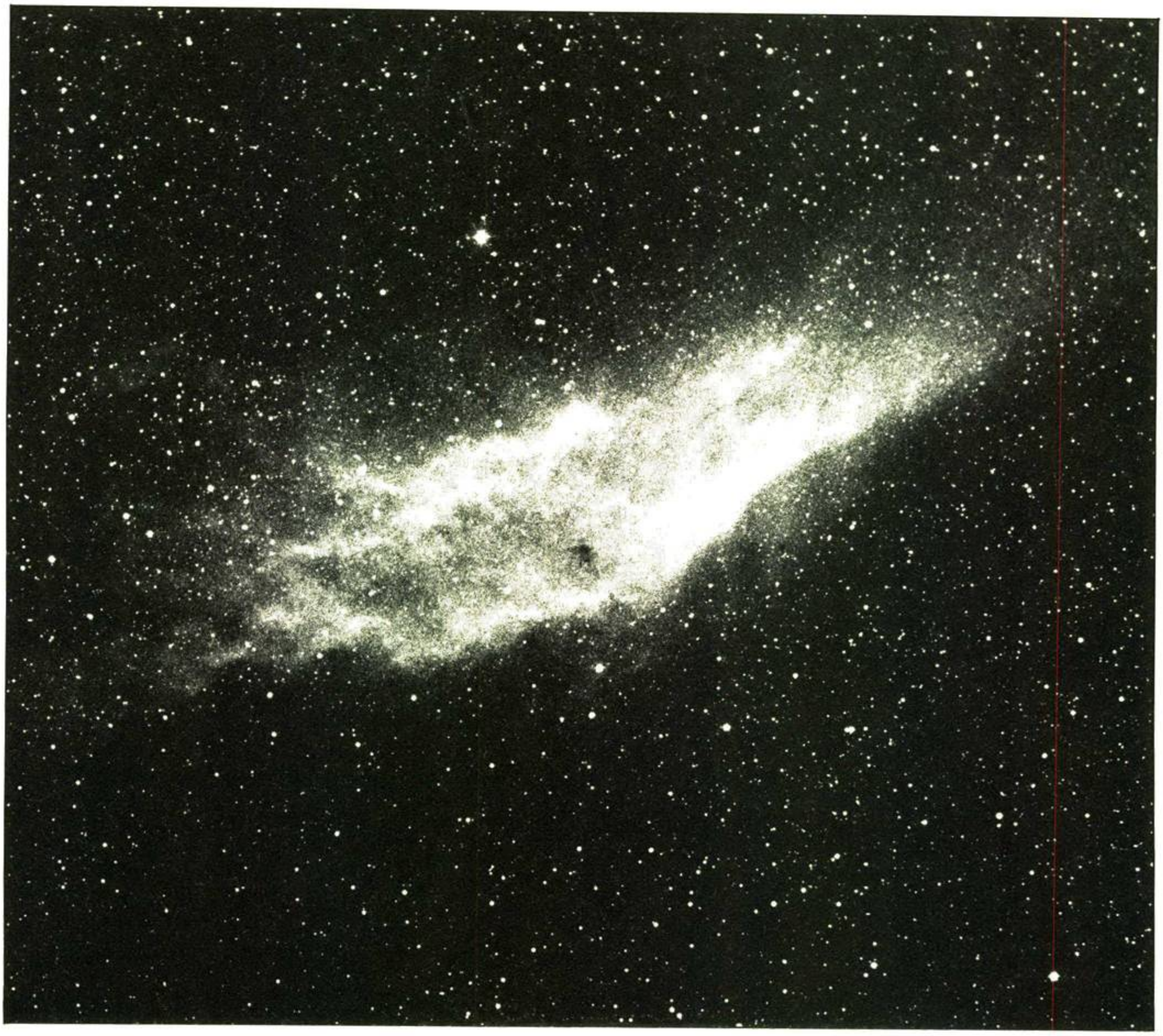
A more effective filter is the Schott RG-645 which doesn't let any of the 6300 A and 6360 A airglow through. With it your exposures will be longer because its transmission of H-α is only half of 103a-E's natural sensitivity.

Even more exotic — and expensive — are the interference filters made by PTR Optics which are very selective, i.e., they let H-α through and not a lot else. However, their transmission



The right film and filter can work wonders! Above left: NGC-7000 on 103a-E, Wratten #29 filter, half-hour exposure near New York City. Middle: 103a-E, no filter, 30 minutes under a dark sky. Right: 103a-E, Wratten #29, and a 1-hour exposure at the same dark sky site. All three taken with a 300 mm f/5.6 lens by Les Yuill. Below: 103a-E, Wratten #92, and 15 minutes at f/1.5 in an 8-inch Schmidt. Photo by David Healy.





The California Nebula (NGC-1499) in Perseus is one of the more frequently overlooked red nebulae, but its large extent (145′ x 40′) often comes up nicely on film. David Healy used his 8-inch f/1.5 Schmidt camera in Naco, Arizona for this 18 minute exposure. His film was 103a-E and the filter, Wratten #92.

losses are large. Also, interference filters work best when the light impinges on them at right angles to their surface — a requirement hard to meet over the whole image field with fast (low f-ratio) optical systems. (Placing it in front of your camera lens would get around this problem.)

How Much Is All This Gonna Cost, Anyway?

What about practicalities? There's no doubt that you can get started with a roll or two of 103a-E and either of the photostore-available Wratten filters. If you want, you can spend even less by purchasing the gelatin versions — but treat them very carefully. Moisture and rough handling will easily do them damage.

Schott filters can be ordered from Schott Optical Glass Co., Duryea, PA 18642. The RG-645 filter is 2 inches square. It costs $15 (Schott's minimum order is $30, so buy two or go in with a friend on the order). Write to Jim Speicher, Product Manager.

PTR Optics is at 145 Newton St., Waltham, MA 02154. They make several H-α interference filters: the one with a 100 A bandwidth costs $91 and the 30 A bandwidth $127. (Even tighter bandpasses than these are also available.) Filters come in 1-inch diameter circles and 2-inch squares. PTR's catalog is free on request; write to John Mead.

How Do You Use Them?

Mount the filter in front of the camera lens or, if you are using a telescope, where the whole of the image can pass through it. Glass or gelatin, it must be held securely and free from wobble — otherwise accidental double-imaging is likely. A small investment in a good filter holder will pay for itself every time you don't have to fumble around in the dark with tape. (You'll keep that filter cleaner, too.)

Since most of the nebulae are faint, the necessary exposures are long, often averaging an hour under ideal conditions. With 35 mm cameras, a telescope with a good clock drive will take the drudgery out of piggyback exposures. Even so, to reach the faintest nebulae, you may find yourself running two to four hour exposures!

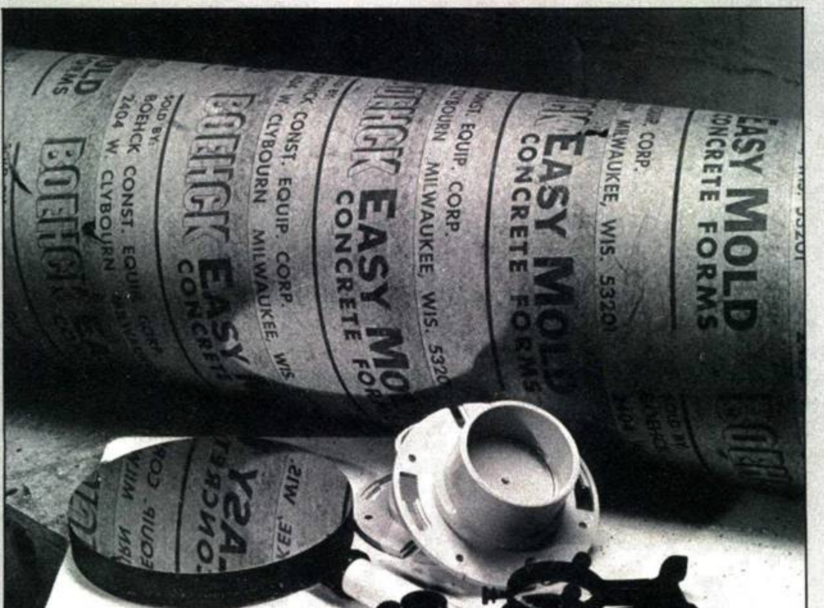
Typical urban or suburban skies will cut your exposure times down to between 5 and 30 minutes, but give it a try anyway — you'll get better results than you would by shooting "bare." The exact exposure time depends on your optical equipment; trial and error will quickly show you what works best. Keep accurate records and develop and examine your negatives from one outing before you shoot the next batch.

— *Robert Burnham*

how to build a dobsonian telescope, part 2

by Bob Kestner and Richard Berry

After you've obtained the materials (either exactly what's specified in "How to Build a Dobsonian Telescope, Part 1," in the June 1980 issue or the best substitutes you could find), you're ready to determine the dimensions for your 10" telescope's mount. (Warning: Since the dimensions of the mount depend on the balance point of the tube, it helps to assemble the tube and optics first if you plan to make your telescope unusually heavy — for example, if you use a fiberglass tube with a cast aluminum mirror cell.) If you're building according to these directions, you can safely assume that the balance point will lie close to 20" from the rear of a tube 60" long, and rely on the capacity for adjustment inherent in the design.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Dimensioning

Let's get started. The entire mount is made from ¾" plywood. A 4' x 8' sheet is more than enough, and you may find you have enough scraps on hand if you're a do-it-yourselfer. First, the box for the tube must be designed. With a cardboard tube, it's a good idea to make the inside of the box about 1/16" less than the outside diameter of the tube; this holds the tube firmly. (For stiff tubes that don't warp under pressure, build to the exact dimensions.) For 12" Sonotube, which is usually 12½" outside diameter, this gives us a box with inside dimensions of 12-7/16". The box will have two side boards this dimension and two top and bottom boards 1½" longer, to overlap the thickness of the side boards. It's a good idea to have the box enclose about one diameter of the tube (or 12"), so the final dimensions are:

Tube Box Parts
2 pieces 12" long x 12-7/16" wide
2 pieces 12"long x 13-15/16"wide

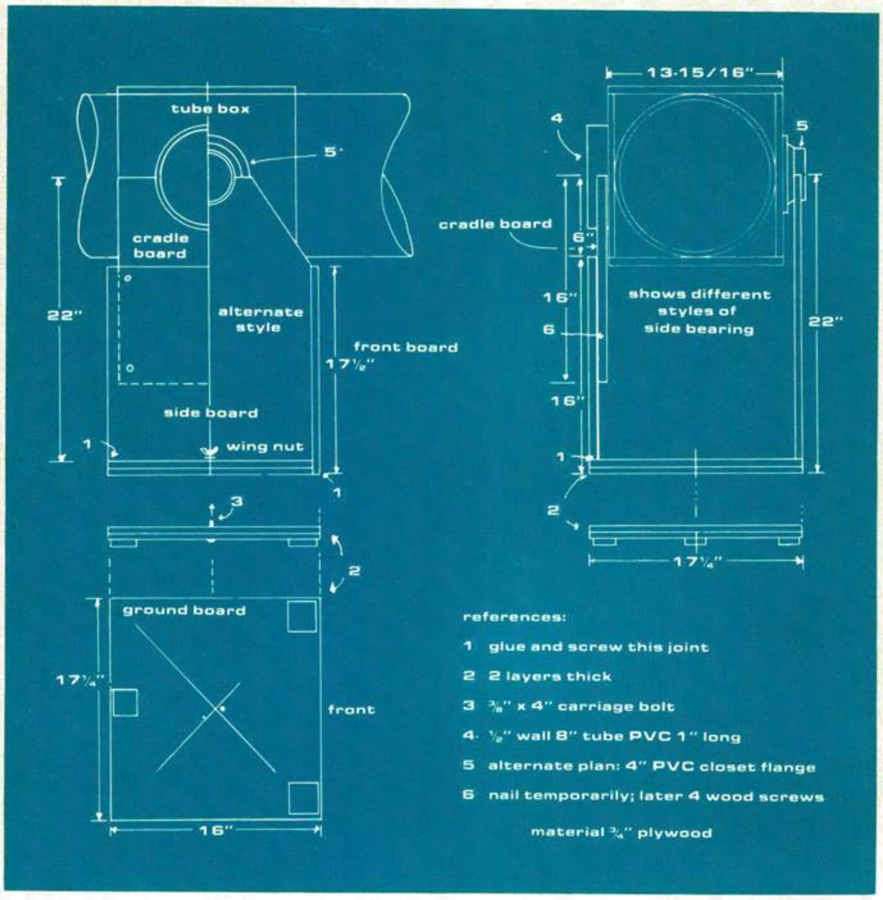
Next, we'll figure out how far apart the outside surfaces of the side boards on the rocker must be. The width of the box is 13-15/16". If you allow 5/16" for clearance between the box and the cradle boards (or 5/32" on each side), plus ¾" for the thickness of the cradle boards on each side, and ¾" for the thickness of each side board, the total width of the rocker is 17¼". This dimension is the width of the bottom, the ground, and the front boards.

(If you use closet flanges for your bearings, be sure to allow for the extra width the flange part of the plastic casting adds. Another alternative, for rigid tubes only, is to eliminate the tube box altogether and bolt the flanges directly to the tube.)

Next we must determine the height of the side boards and cradle boards. For a Dobsonian built according to this article, the tube will balance about 20" from the rear end. We'll add 2" for safe clearance, so the pivot point of the tube box is 22" above the bottom board. Somewhat arbitrarily, we'll set the height of the side boards at 16", so the cradle boards, which go inside the side boards and actually support the tube, will extend 6" above the side boards. We'll overlap them by 10", so the cradle boards are 16" long also.

The cradle boards are usually made the length of the tube box, or 12". Remember, in the top of each cradle board, you will be cutting a semicircle to hold the side bearing. Their final specifications are:

Cradle Boards
2 pieces
12" wide x 16" high



The width of the side boards is not very critical, so to use plywood most efficiently, we'll assign them a width of 16". The final dimensions then are:

Side Boards
2 pieces
16" high x 16" wide

The bottom board, which is two layers of wood thick, is the same length as the side boards. It must be as wide as the rocker, whose width we figured out earlier. If you are using a sink cutout attached to ¾" particle board for your formica sheet, then you need only one piece of plywood. If you're going to glue the formica directly to the bottom board, you'll need two pieces. Its dimensions are:

Bottom Board
16" long x 17¼" wide
2 layers thick

The ground board should be the same dimensions as the bottom board, and is made of two layers of ¾" plywood glued together.

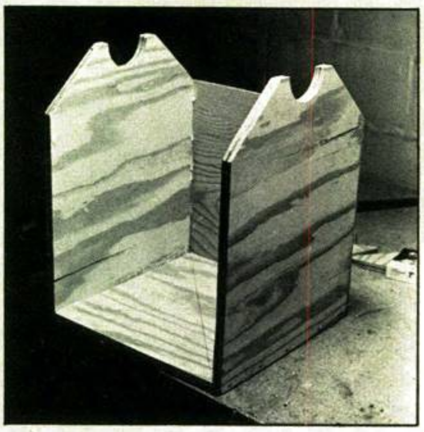
Finally, the front board is the width of the rocker, or 17¼". It should be high enough to give ample stiffness to the side board, but not so high as to restrict the tube from being pointed horizontally. Since the centerline of the tube is 22" above the bottom board and the tube extends 6¼" below that, the front board could be as much as 15¾" high. Since it overlaps the front of the bottom board, it needs another 1½", for a total of 17¼". For the sake of good looks, however, make it 17½" high (the total height of the side board above the bottom of the bottom board) and cut a shallow circular cutaway to accommodate the tube. Thus, we obtain:

Front Board
17¼" wide x 17½" high
with cutaway

(If you want to try a variation on the basic Dobsonian design — such as making the side boards and the cradle boards one single piece or eliminating the tube box entirely and attaching closet flanges directly to the tube — work out your own dimensions in the same way we've done here.)

Cutting and Gluing

Make a scale drawing and figure out the most efficient way to cut these pieces from a standard 4 x 8 sheet of plywood — or whatever scrap pieces you have on hand. Don't be discouraged if you don't have a shop full of equipment. You can cut them out perfectly well with a hand saw, though it is rather tedious. Your only concern should be keeping the edges that are to be joined reasonably flat, straight, and square. Afterwards, you can touch them up with a wood rasp and coarse sandpaper if there are minor deficiencies in craftsmanship. In most respects, you can build your Dobsonian as crudely as you like without detracting from the instrument's performance.



Begin by gluing the double thickness boards — that is, the ground board and bottom board — together. Smear glue on both surfaces, line them up, then press them together and drive in several small nails so they won't slide around. Clamp them firmly together, or put them under heavy weights, and let the glue set. Meanwhile, cut the semicircles in the cradle boards and the cutaway in the front board. A jigsaw is ideal, but a handheld keyhole saw works well, too.

You're going to glue all the joints and nail them down tight. White wood glue and galvanized nails give fine results, but waterproof resin glue and woodscrews weather better. It's your choice.

When the boards are ready to go, start by driving 3 or 4 galvanized nails through the bottom board on each side where the side boards are to be attached. Gently tap the nails back almost flush with the surface, then run glue along the bottom of the side boards and the top of the bottom board. Place them together so the sides are exactly flush to the sides and front of the bottom board, and drive the nails all the way in. Next, glue and nail the front board on over the ends of both side boards and the front board. Assembling them this way holds the side boards on and insures the correct spacing between them.

Build the tube box the same way, making sure the two shorter boards (the sides) go between the two long (top and bottom) boards.

For maximum stability, the ground board should be raised off the ground on three feet. The feet can be little scraps of ¾" plywood about 2" square. Nail (to the bottom side) two of the feet in the front corners and one in the center of the back of the ground board. They make the groundboard a tripod.

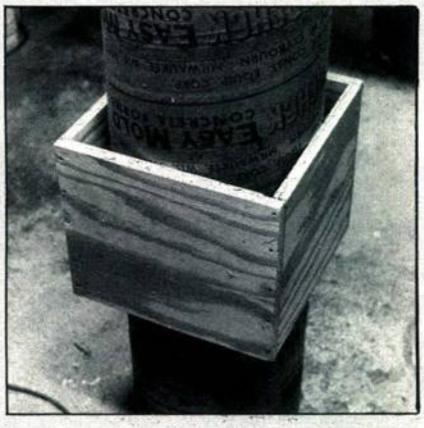
Homemade Precision Bearings

On the top side, locate the center, then mark a point ½" forward of the center, and drill a 5/16" diameter hole there. Now drill a ⅜" hole through the corresponding place in the bottom board. Force a ⅜" x 4" carriage bolt through the ground board from the underside. (If this takes too much pounding, file the hole out a little larger and try again.) This is your center bolt.

For this 10" telescope, you'll need three pieces of teflon for the bearing about 1½" on a side (the shape doesn't matter, but use 2 square inches in each). Mark the biggest circle that will fit on the ground board, and space the teflon pads equally around it. Nail them down with small finishing nails, taking care to sink the heads of the nails well into the teflon (use a nail set, or another nail, for this).

Now place the rocker on the ground board so the center bolt protrudes through the bottom board. Drop two washers over the bolt, and screw down the wing nut, and it's ready to go. When you push the rocker box, it will rotate smoothly on its precision teflon and formica bearing. The tighter you turn the wing nut down, the more friction you'll have. Normally, however, you won't want any extra friction.

The side bearings are formed by PVC plastic — whether it's a length of 8" diameter tube or a closet flange — running on small teflon pads nailed to the cradle board. First cut a semicircle centered top center on the cradle board, with a radius ⅛" larger than the radius of the side bearing. Cut pieces of teflon ¾" wide by 1" long and nail them (again recessing the nailheads) about halfway up the sides of the semicircle. Attach the bearings to the side box (or tube, if you're doing it that way), taking care to get them dead center and accurately opposite each other.

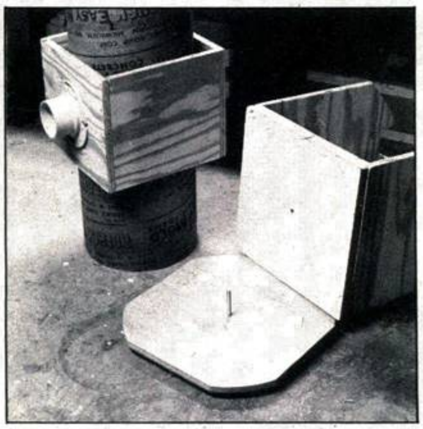


Center the cradle boards about ¼" ahead of the center of the side boards, and at exactly the same height. Drive three or four small nails to hold them in place temporarily, then check that the tube box fits between them properly and swings with the proper clearance. Later, after the telescope tube is completed and you're sure everything is adjusted correctly, attach each cradle board permanently with four wood screws.

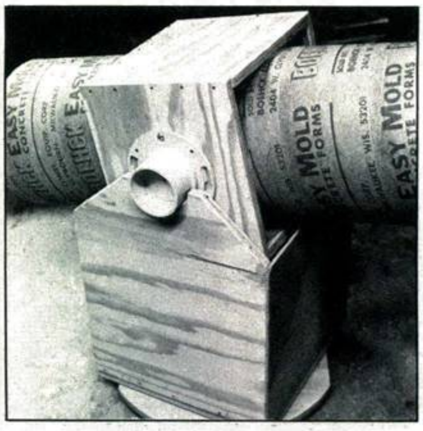
This completes the telescope mounting except for finishing. We recommend that you sand all surfaces, then use a penetrating sealer to waterproof all wooden parts, followed by two coats of a good grade enamel or polyurethane varnish.

Preparing the Tube

Six feet of Sonotube concrete form casting tube may not look very auspicious when you get it home. It will have a waxy coating, will probably be slightly squashed from being stored under a big heap of other tubes, and may have raggedly cut ends. Sonotube varies greatly from place to place in the U.S., so it's difficult to prescribe exactly how you can best fix yours up.



First, you should clean the wax off if possible. Part of the reason for getting six feet, when you really need five feet, is to allow for some experimenting. Sometimes the wax is coated on a very thin spiral sheet on the outside, and can be removed simply by peeling the paper off. If the paper is thicker, you may not want to remove that much thickness. Try putting the tube out in bright hot sunlight for several days. Given this treatment, some waxes evaporate or diffuse into the tube. Finally, wax is usually soluble in carbon tetrachloride or a general solvent like varsol, and can be dissolved. The fumes from these solvents are poisonous, so do this outside on a breezy day.



Once the wax is off, cut the tube to length (60" for a 10" f/5.6 mirror) making the ends perfectly square. Do one end first, then the other. Here's how: wrap a thin strip of paper, such as adding machine paper, tightly and completely around the tube so the ends meet. Trace the edge of the paper. Use a sharp utility knife to cut the tube. Measure off 60", mark, and cut the other end similarly.

For reinforcing the tube at the upper end, you may wish to cut a plywood ring about an inch wide to fit tightly around the outside of the tube. This is optional, but it looks nice and it helps keep the tube strong.

Now test the cutoff ends to see if their inside and outside surfaces accept a penetrating sealer and primer coat for oil-base paints. If they do, all is well. Prime, sand, and paint the outside any colors you want (light colors are best for working in the dark). Paint the inside with a flat black enamel. This process is incredibly messy if you use a brush and reach in with your arm, so bolt the brush to a 1" x 2" piece of wood as an additional handle. Give the tube plenty of time to dry between coats.

This is the second of a three part series on building a Dobsonian telescope. Part 1 deals with the materials and where to find them; part 2, how to assemble the mounting for the telescope; and part 3, how to build accessories and install and align the optics.

Bob Kestner is a long-time designer of Dobsonian telescopes, and is employed as a professional optician. In addition to helping many others in the San Francisco area build Dobsonians, he has completed an 18" of his own, and has written about Dobsonians in TELESCOPE MAKING #4 and #5.

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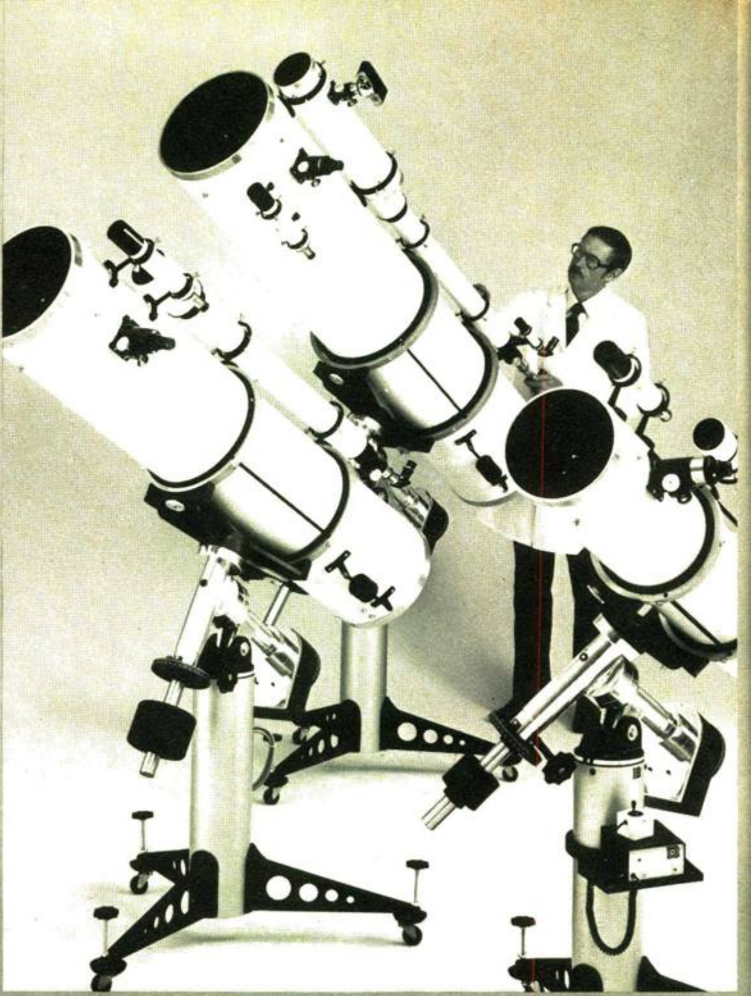

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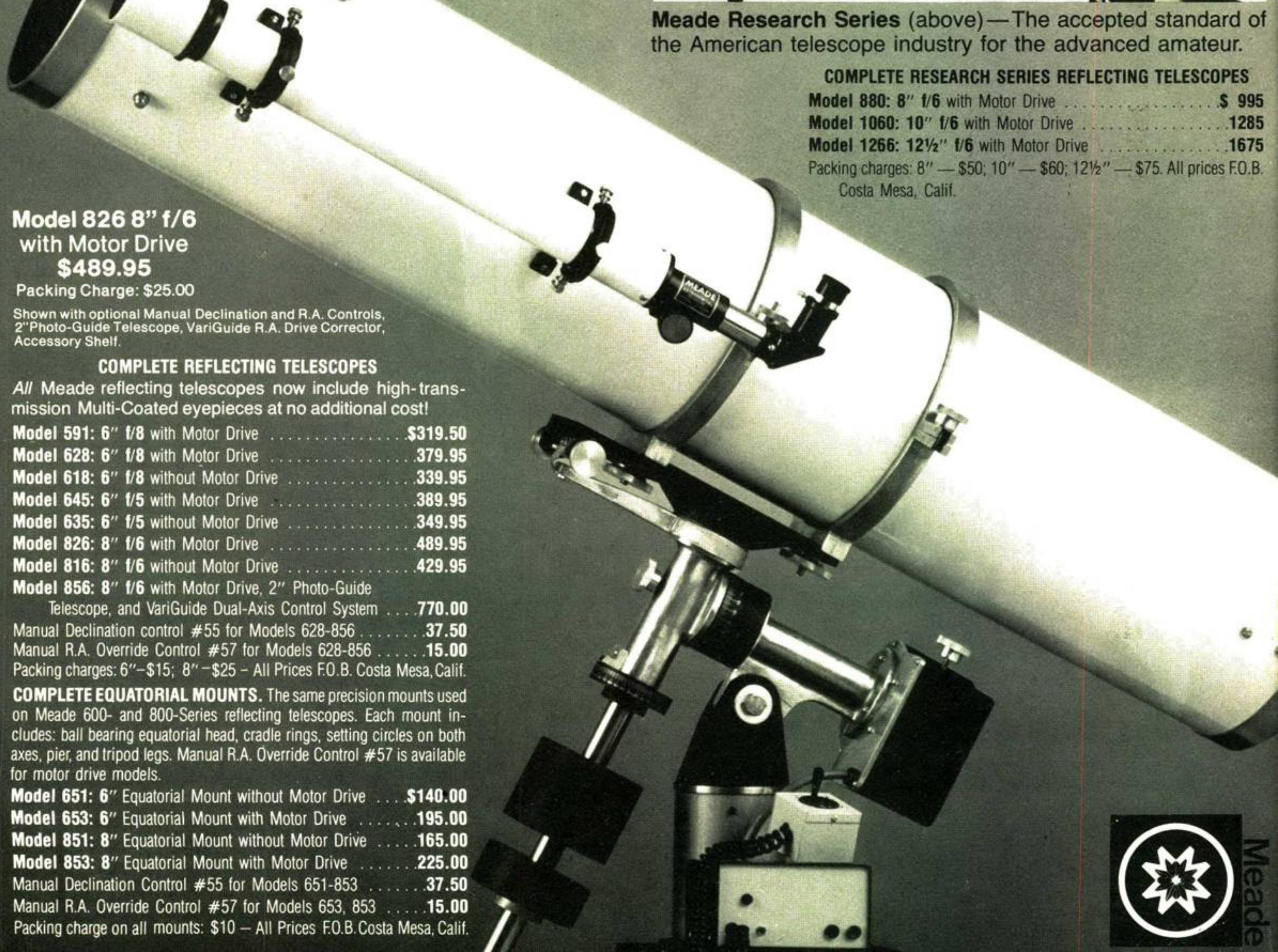

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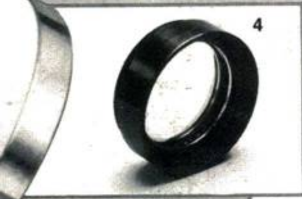
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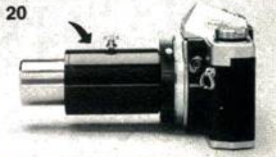
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gazer's
gazette

observing diffuse nebulae

by
F. Michael Witkoski

lagoon nebula

by roger silva

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A closer look will reveal something else very special. In the Sword of Orion, hanging south from the three Belt stars, lies a hazy blotch just visible without optical aid: the famous Orion Nebula.

Almost directly opposite in the sky and readily seen in summer, are the Lagoon (M-8), the Trifid (M-20), and the Omega (M-17) Nebulae. Together with the Orion Nebula, these four objects are the most renowned of the diffuse nebulae.

Of all deep-sky wonders, diffuse nebulae are the most diverse in appearance. Globular (and even open) clusters look generally similar to others of their types, and while galaxies take on different shapes, they don't vary all that much, particularly when viewed through a small or medium-size telescope. Planetary nebulae do exhibit differences from one to the next, but like the galaxies, their forms are pretty restricted. None of this holds for the diffuse nebulae: they can adopt any imaginable shape.

How? Basically, a diffuse nebula is what you get when a volume of very tenuous hydrogen gas is interspersed with small, varying amounts of other elements, collectively called dust. Charged to glow by the radiation from young, hot stars embedded within, a nebula is the birthplace of stellar clusters.

The gas, though spread very thin, is also very extensive; its total mass often exceeds that of a typical star (such as the Sun) by many, many times. The internal gravitational attraction of the nebular gas and dust, compounded by the influence of neighboring stars, generates constant turbulence causing an infinite variety of shapes.

Random internal motions assure that certain parts of the nebula will coalesce, becoming much denser and eventually collapsing into new stars. Turn your small telescope or even a good pair of binoculars onto the Lagoon and Orion Nebulae. These are prime locations where this process is happening now.

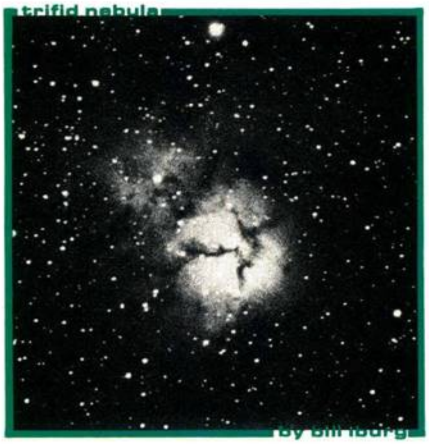
The Lagoon Nebula, a naked-eye object located in Sagittarius approximately 6° west of third magnitude Lambda (λ) Sagittarii, and its associated cluster, NGC-6530, both afford a firsthand glimpse into a star factory and its output. Through a 3-inch instrument you'll have little difficulty seeing the two dozen brightest stars in the cluster — but give your eyes time to dark-adapt if you want to appreciate the view fully.

With increasing telescope aperture and/or better observing conditions, you'll experience a dramatic improvement in the view as the contrast between the bright nebulosity and several dark areas increases. Particularly obvious is a large northeast to southwest trending dark lane bisecting the nebula and suggesting a canal — or by stretching the imagination, a lagoon.

While a low power, wide-field eyepiece works best, the nebula is large and bright enough for you to try higher powers when the "seeing" is steady.

The Trifid Nebula lies a mere degree and a half north-northwest of the Lagoon, and the two are probably physically associated. Characterized by a series of radially extending dark channels, the Trifid breaks into three major sections and so earns its name.

trifid nebula



by bill iburg

In the center lies a multiple star, two of whose components are seen easily with modest optical aid. They serve as quick (and sometimes necessary) reference points, since the nebular details are generally difficult to see under less than superb sky conditions. But careful reference to published photographs, averted vision (looking to one side of the object), and patience will all help substantially. With a little practice, you'll find exploring this object isn't difficult at all, but fun.

The Omega Nebula resides some 8° north-northeast of the Trifid and Lagoon. Its angular size falls approximately midway between its two neighbors, and because its surface brightness nearly matches the Lagoon's, it shows up well under a range of magnifications. Also, being at a more northerly declination, it's much better situated for most mid-northern latitude observers than the Lagoon and Trifid — which you often have to look at through thick layers of southern horizon murk.

Containing no obvious bright stars (though lying in a fairly rich field), the Omega Nebula looks most like a bow of luminosity floating in an open sky. The similarity of its shape to the Greek letter omega (Ω) logically suggested the name, at least among the classically-educated early sky observers. However, three additional common identifications — the Horseshoe, the Checkmark, and the Swan — are also popular now. Depending on your imagination, any or all of these are appropriate.

So far this little tour has been easy. Want to try for something more difficult? Let's take a side trip a few degrees north of the Omega Nebula to the constellation Serpens. Here lies a large open cluster, M-16, embedded in a swath of luminosity known as the Eagle Nebula. About equal in size to the Omega (and a marvelous photographic subject, too), the nebula reveals itself only very subtly to the eye.

However, a dark sky will show it well and when you do finally see it, the Eagle displays scattered dark patches accompanying well-defined angular outlines. It offers an interesting contrast to its much brighter counterpart. And as with the Trifid, you'll find referring to photos helpful.

Farther to the north along the Milky Way is the North America Nebula, one of the best in the whole sky. Large and spread-out, the nebula lies about 3° east of Deneb (Alpha [α] Cygni) at the same declination.

It's so spread-out that you'll probably appreciate it best in a wide-field telescope or binoculars. The nebular gas has a well-defined edge where it meets the backdrop of the Milky Way and this helps you pick it up as you scan past.

The overall shape of the continent is remarkably well displayed, especially the "Gulf Coast" which surrounds a small bay of obscuring dust. Elsewhere, many hot, bluish stars are strewn across the face of the nebula. This is a fine subject to come back to again and again to explore.

Now let's make that temporal jump again and return to the Orion Nebula. Spectacular yet sublime, it graces us with one of the most satisfying sights in all the heavens, so large and impressive that Messier gave it a dual designation in his list: M-42 for the main body and M-43 for the partially detached smaller portion to the northeast.

A quick glance through a small telescope shows four closely spaced fifth magnitude stars, officially known as Theta^1 (θ^1) Orionis (commonly called the Trapezium), and the outline of a massive body of gas from which more stars will form in the future.

You'll best appreciate the elegance of the Trapezium and its environs visually, since photographs exposed long enough to capture the nebula's filamentary outer wisps unavoidably overexpose and "burn out" the inner parts.

Looking through progressively larger instruments will partially reveal the various nebular features you see in photographs. Especially striking is the change in the intensity of the nebula's eerie greenish cast as you proceed from a 3-inch telescope to, say, a 12-incher. Covering over a square degree of sky and gracefully streaming away from the Trapezium stars, the Orion Nebula is sprinkled with dimmer stars through its finely detailed filaments.

Because its stars are among the youngest visible anywhere, the Orion Nebula is prized as much by the astrophysicist specializing in stellar evolution as it is by the casual observer viewing for pleasure from the backyard.

Starkly contrasting with the mighty Orion Nebula is the diminutive diffuse nebula M-78 (also in Orion), visible in a modest telescope as an irregular blob of light associated with two 10th magnitude stars. You'll find it about 2½° northeast of Zeta (ζ) Orionis, the easternmost Belt star.

While the Orion Nebula's immediate neighborhood is among the sky's richest, prosaic little M-78's claim to fame is its location amidst a patch of dark nebulosity, an area where obscuring dust absorbs much of the light from the glowing background and creates an apparent "void in the heavens."

Despite dull surroundings, don't pass M-78 by unobserved. Keen-eyed observers will note an abrupt transition from light to darkness at the western edge in contrast to a gradual blending of the nebular surface with the background at the opposite side.

Monoceros, a constellation northeast of Orion, is the home of an unusual and visually challenging nebula, the Rosette. Surrounding the open cluster NGC-2244 and almost lost in its brilliance, this extensive cloud of gas most resembles a Christmas wreath.

Large enough to carry four NGC designations (2237, 2238, 2239, and 2246), you'll detect it only on the most ideal of nights — and even then with difficulty — due to its low surface brightness. A moderate size, richest field, low-power instrument undoubtedly works best for the Rosette.

Many areas of sky along the Milky Way abound with patches of nebulosity in varying sizes and shapes. However, most are so spread out or dim as to defy visual detection, though lots will appear almost magically in wide-field photographs.

To wind up this survey of diffuse nebulae, let's take a look at some objects that resemble them superficially: supernova remnants. (Keep in mind, though, that diffuse nebulae and supernova remnants in reality fall at opposite ends of the evolutionary spectrum: the former represent stellar nurseries; the latter, their gravestones.)

Of the very few examples known, the most familiar is M-1, the Crab Nebula, in Taurus. Resembling a small diffuse nebula, the Crab is an amorphous mass of debris, the aftermath of a stellar explosion so violent its light could be seen in broad daylight. The event was recorded by Oriental astronomers in 1054 A.D.

Discerning the Crab through small telescopes isn't too difficult, but no great detail will be evident. More aperture will reveal a "curdled" texture and perhaps a hint of filamentary structure. What's impressive is the realization that you are seeing one of the most studied and celebrated of all celestial objects. To find the Crab, look a degree northwest of the star Zeta (ζ) Tauri.

One other supernova remnant is visible using modest optical aid. Just above the southern border of Cygnus, near the 4th magnitude star 51 Cygni, lies a widespread system of filaments collectively known as the Veil (or Loop) Nebula.

Having two designations, NGC-6960 (the part lying close to 51 Cygni as seen from Earth) and NGC-6992 (a brighter section 2½° east-northeast), this system as a whole is best appreciated in a wide-field instrument. (See the photo on pages 16 & 17 of the June 1980 ASTRONOMY.) Considering them individually, NGC-6960 presents a challenge for telescopes smaller than 10 inches, while brighter NGC-6992 can be found using good binoculars under excellent conditions.

In comparison with the much younger Crab Nebula, the Veil is probably a few tens of thousands of years old. Being older naturally accounts for its more diffuse appearance; one day the Crab will look like the Veil does now. But for the present, both are quite unique and sometimes it's hard to believe they are members of the same class of object.

"Collecting" diffuse nebulae in your eyepiece is a fascinating experience. Pretty sights, fantastic shapes — it's easy to feel their lure. Yet in the end, perhaps the most rewarding pleasure of all is simply setting your mind's eye free to explore the places where the stars come from.

what does a nebular filter show?

The diffuse nebulae are full of glowing hydrogen that radiates mostly in the red region of the spectrum. But hydrogen also radiates in the blue-green colors to which your eyes are most sensitive. By transmitting light at or near that of hydrogen while suppressing airglow and light pollution in neighboring colors, the filter allows a greater contrast between the nebula and the sky.

Through a filter the Lagoon Nebula sharply splits into two distinct pieces, the rift in the middle becoming nearly as dark as the surrounding sky. The northwest end of the nebula (the brightest) stands out to a striking degree. The associated star cluster, as eye-catching as the nebula itself when seen unfiltered, is dimmed considerably by the filter.

The Trifid, not nearly so spectacular as the Lagoon when observed under equal conditions, appears brighter through a filter than its neighbor does without one. Although the double star is dimmed considerably, the three major divisions become very noticeable, especially with averted vision.

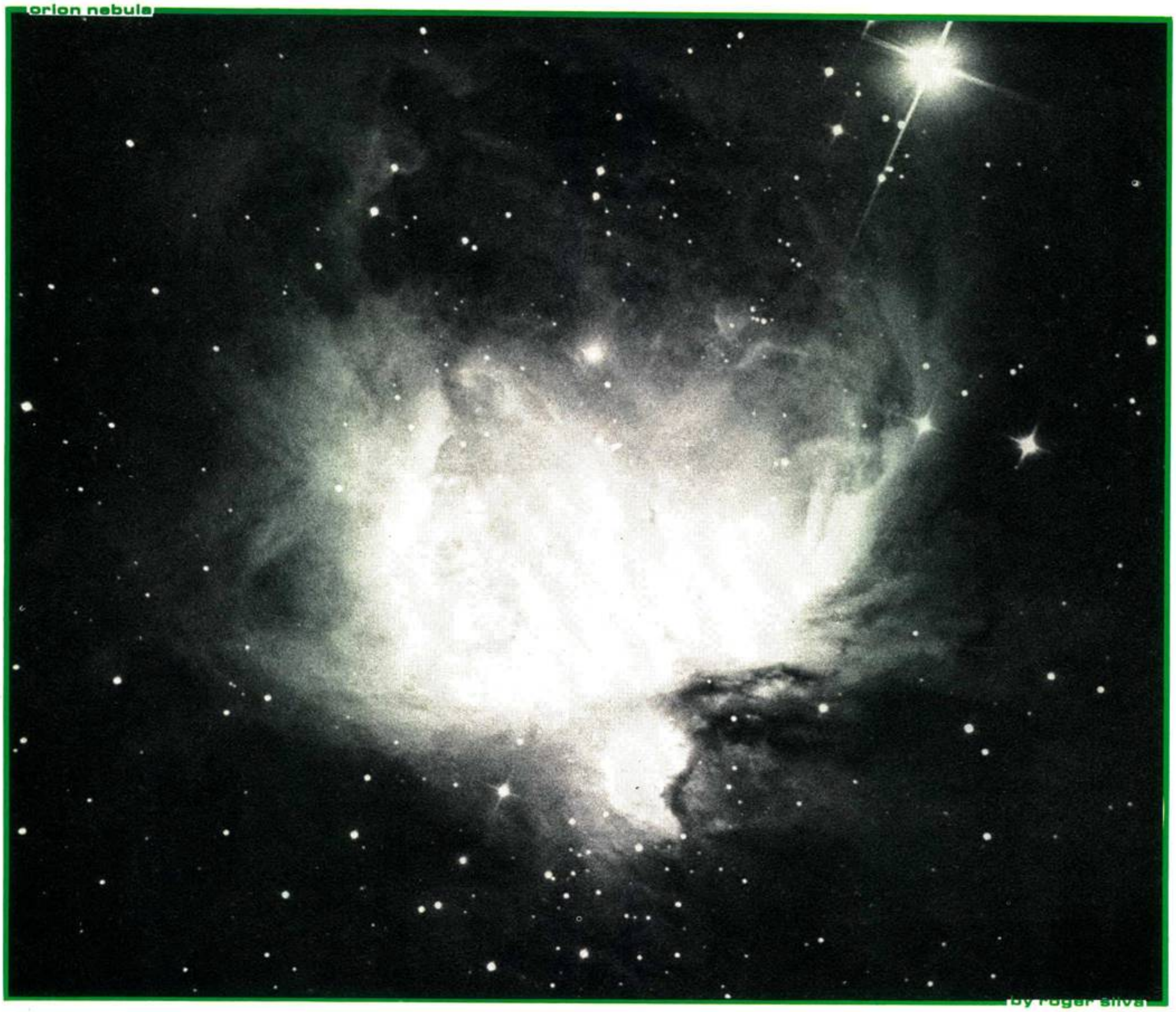
The enhancement of the Omega Nebula is generally similar to that of the Lagoon and Trifid, but since it isn't accompanied by any bright stars, it ends up having much the same basic configuration.

The Orion Nebula, because of its intrinsic brightness, can absorb some abuse by sky-glow and light pollution, though naturally a filter turns a good look into a spectacular one. One drawback is that the Trapezium, an integral part, loses much of its luster.

Our two supernova remnants give surprisingly divergent results. The Crab weakens significantly, but the Veil is greatly improved and especially so with large telescope apertures.

One reason for the discrepancy is that most of the Crab's light is continuum radiation (because it's so hot), whereas the cooler Veil shines mostly by hydrogen light.

orion nebula



by roger silva

where to look

NGC	other	cons.	r.a. (1950)	dec.	size	comments
	M-45	Tau	$03^{h}\,44.5^{m}$	$23^{\circ}\,57'$		seen around Merope
1499		Per	04 00.2	39 16	154′ x 57′	California Nebula
1936		Dor	05 22.4	–68 01		in Large Magellanic Cloud (LMC)
1952	M-1	Tau	05 31.5	21 59	6 x 4	Crab Nebula; supernova remnant
1976	M-42	Ori	05 32.9	–05 25	66 x 60	Orion Nebula main part
1982	M-43	Ori	05 33.1	–05 18		Orion Nebula small part
2068	M-78	Ori	05 44.2	00 02	8 x 6	small, has dusty regions
2070		Dor	05 39.9	–69 04	20 x 20	Tarantula Nebula (in LMC)
2237		Mon	06 29.6	04 40	80 x 60	Rosette Nebula
2261		Mon	06 36.4	08 46	2 x 2	Hubble's Variable Nebula
3372		Car	10 43.1	–59 24	120 x 120	Eta Carinae Nebula
6514	M-20	Sgr	17 59.6	–23 02	29 x 27	Trifid Nebula
6523	M-8	Sgr	18 00.7	–23 24	30 x 40	Lagoon Nebula
6611	M-16	Ser	18 16.0	–13 48	35 x 35	Eagle Nebula
6618	M-17	Sgr	18 17.9	–16 12	46 x 37	Omega Nebula
6888		Cyg	20 10.7	38 16	18 x 12	
6960		Cyg	20 43.6	30 33	70 x 6	Veil Nebula
6992		Cyg	20 54.4	31 30	73 x 8	Veil Nebula
7000		Cyg	20 57.0	44 08	120 x 90	North America Nebula

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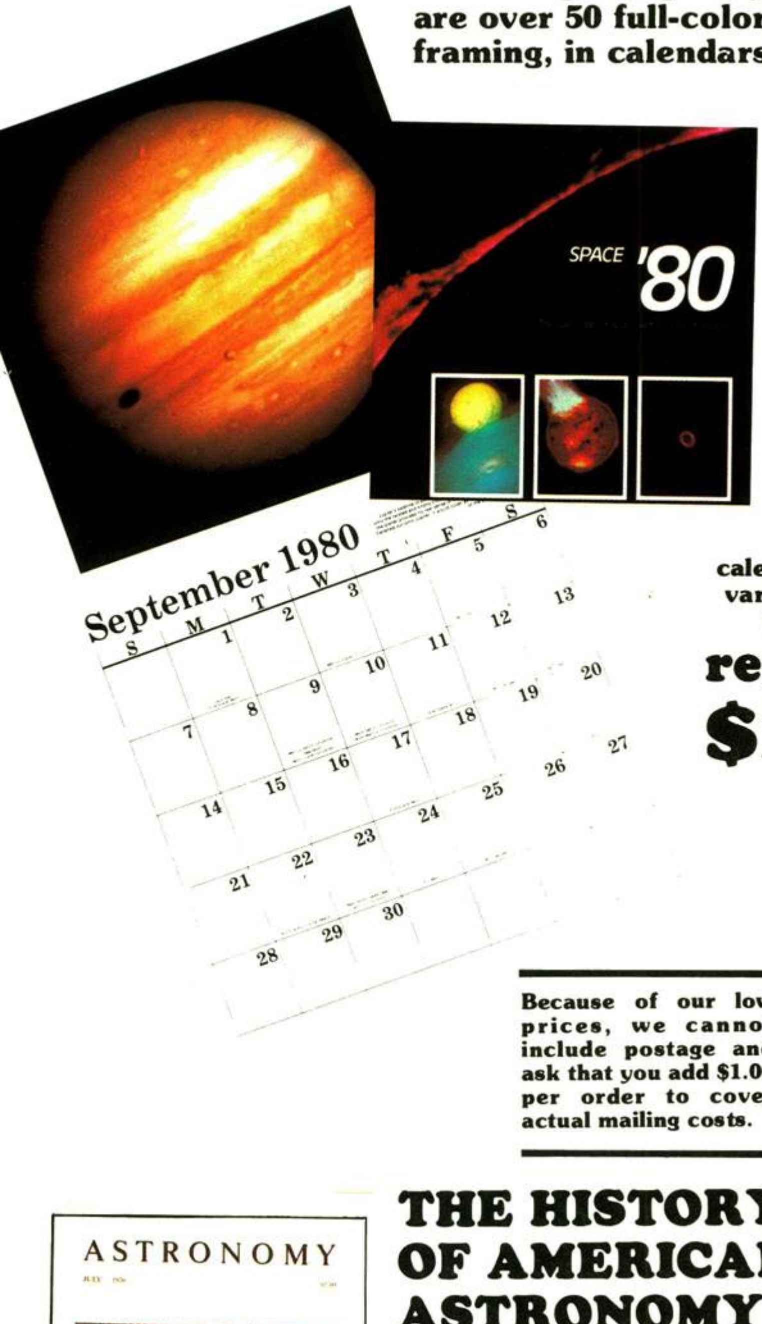

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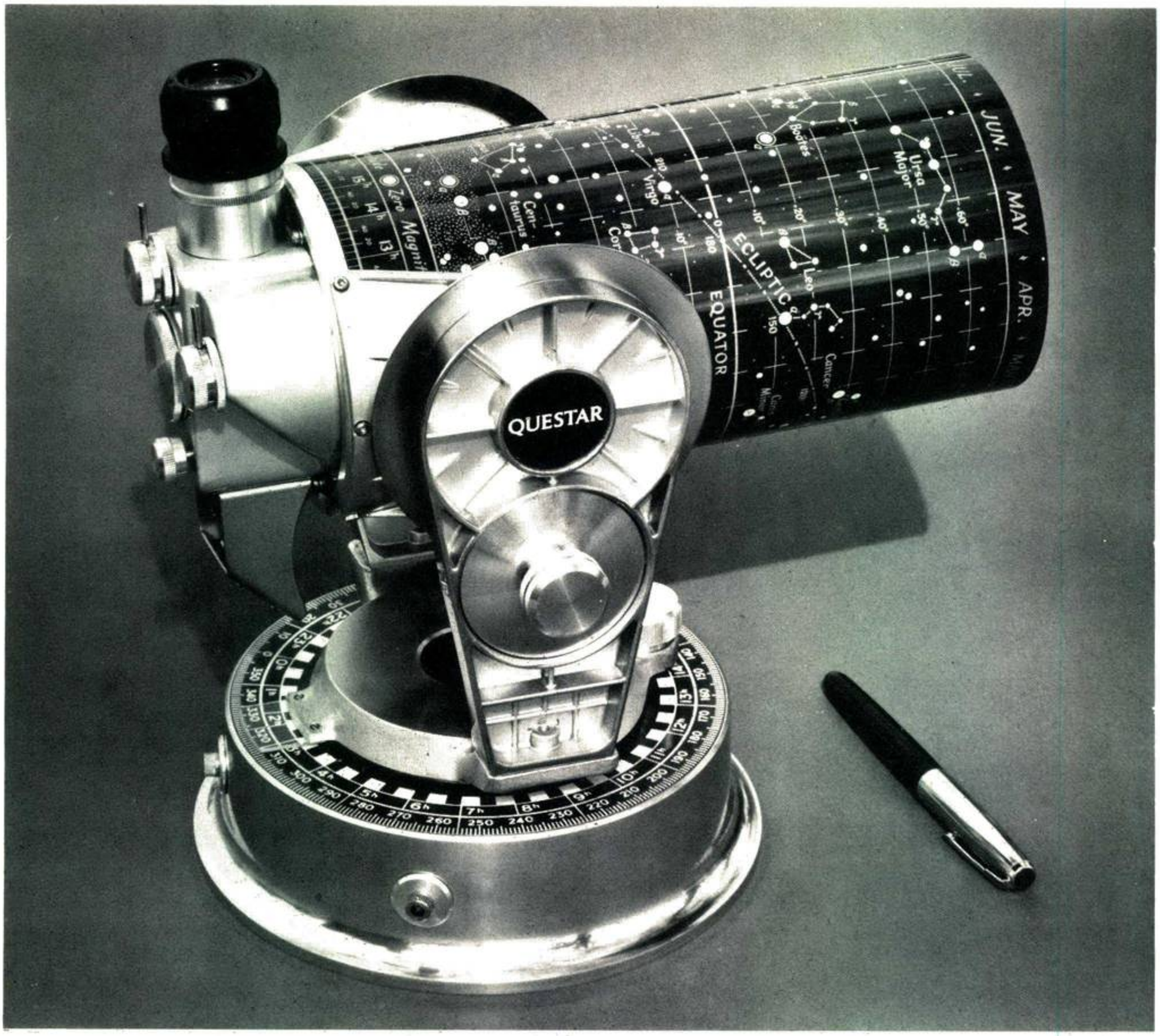

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An Astronomical Expedition

Sir / In the several years that I have been an amateur astronomer, I have experienced a number of very satisfying moments. Finding my 108th Messier object, watching a total solar eclipse, successfully photographing and classifying stellar spectra, and discovering a minor but previously unknown lunar mountain during a grazing occultation, are among the high points. But last summer I had an experience which was even more intensely satisfying than these. From September 9 to 30 of last year, I was at Maria Mitchell Observatory (MMO) on Nantucket Island studying variable stars under the auspices of Earthwatch.

It is not often that an amateur astronomer gets the chance to do serious professional astronomy, but this Earthwatch trip offered just such an opportunity. (Earthwatch is an organization which puts together 1 to 3-week trips during which people have a chance to work under the guidance of a professional scientist.)

At MMO, we used a 7½" Cooke astrograph to photograph selected 12° x 16° sections of the sky with 8" x 10" glass plates. About a half a dozen photos were taken on good nights. We were each assigned to a particular variable. In addition to taking plates ourselves, we used the observatory's plate collection (which began about 60 years ago).

We estimated the star's magnitude on every plate on which it appeared — typically 50 to 200 plates — then examined the period of the variable for changes. Among the equipment that we used were a minicomputer, a blink comparator, a measuring machine, and several telescopes. By far the most exciting telescope was MMO's 8" Clark refractor — I have never seen Epsilon Lyrae separated nearly so well.

For the MMO expedition, not including transportation, the price is $685. For more information write Earthwatch, 10 Juniper Road, Box 127, Belmont, MA 02178.

William J. Larson
Minneapolis, MN

Notice to Subscribers

Effective August 1, 1980, the price of a one year subscription to ASTRONOMY will increase to $16, $25 for two years. You may renew or extend your current subscription at the old rate ($15 for 1 year, $22.50 for two years) if your letter is postmarked on or before July 25, 1980. Please, please include your mailing label, complete address, and zip so we can properly credit your account. We will accept new subscriptions at the old rate until the date shown above.

Meteor or Satellite?

Sir / In the March 1980 issue you published a letter from Mr. Eberst and Mr. Pickup on the subject of satellite re-entries into the Earth's atmosphere. The closing line of the letter said that there were at least two re-entries per day and two or three visible from any one place in a year's time.

After reading this I remembered a very strange, bright meteor I observed not long ago. Since I thought it just another bright meteor, I didn't record the time and do not remember the date.

It was about 9:45 p.m. that night and I was just beginning to go inside when I turned around and for no apparent reason glanced at the horizon. At that instant a very large streak of orange light raced over the horizon on a south to north course. And by large, I not only mean long; it was also of considerable width, the largest I ever have observed.

Near the end of its flight, it burst into many bright parts, glowing white and radiating from the center. There was no noise and the event happened rather quickly. At the time I thought it was just an exploding meteor, but after reading the letter in the March issue, I could not help but wonder about it.

Jay Nix
Sardis, MS

Asteroids

Sir / Joel Davis' article "Asteroids: The Flying Mountains" (May 1980 issue) had the minor planet 1976 AA incorrectly identified as 2060 Aten. The correct identification is 2062 Aten. The number 2060 belongs to minor planet 1977 UB, named Chiron, mentioned later in the article. Aten is unusual itself, as it is one of the only two numbered asteroids (2100 Ra-Shalom is the other) that have semi-major axes less than 1 AU.

I might add one other point of interest. As of the April 1, 1980 issue of the *Minor Planet Circular,* 2234 asteroids have been numbered, but 14 of those are presently considered "lost," so there are 2220 asteroids with reasonably well-known orbits.

David J. Tholen
Dept. of Planetary Sciences
Lunar and Planetary Laboratory
The University of Arizona
Tucson, AZ

The Moon Treaty

Sir / I would like to comment on "The Moon Treaty" editorial published in "Return to the Moon" (ASTRONOMY, April 1980).

Many space lawyers, including myself, support the Moon Treaty because we would like to see lunar resource development of the type referred to by Messrs. Michaud and David accomplished as soon as possible. The main objection to the treaty has focused on "the common heritage of mankind" language contained in the treaty. However, this objection assumes that "common heritage" has the same meaning in Space Law as it does in Seabed Law.

Since the two areas of law differ significantly, it is better to interpret the provisions of the Moon Treaty solely in the context of Space Law in order to avoid controversies that have plagued Seabed Law and seriously delayed deep seabed resource development. International cooperation in lunar resource development can be achieved by using the same kind of organizational structures that have enabled INTELSAT to achieve great success in the area of satellite (space) communications.

Jerry V. Leaphart
Cherry Hill, NJ

A Very Young Moon

Sir / A few days ago, I saw what I thought was an interesting sight, a very thin crescent moon with the crescent on the bottom, like a smile. This was the same day of the solar eclipse (Feb. 16th), about 5:40 p.m. in Madison.

Chris Jensen
Madison, WI

Mr. Jensen / Congratulations! Your 14¾-hour-old Moon is one of the earliest on record. The soonest a Moon has been seen after new is 14 hours — and this record was set in 1912.

Whazzat?

Sir / On March 22, 1980, at 7:42 EST, I was observing M-42 through my RV-6 Dynascope using a 70x eyepiece. Before I changed over to my high-powered eyepiece, I decided to take another quick look. As I did, a medium-dim dot of light passed through my field of view in about 2 seconds. It moved uniformly in a straight, downward direction. Could you tell me what I saw?

Douglas Tucker
Belleair, FL

Mr. Tucker / You likely saw the passage of a satellite. Considering how small your angular field of view is at 70x, you were pretty lucky. (On the other hand, people at star parties are always seeing flocks of birds pass over the Moon's face, so who knows? Maybe satellite passages aren't very rare after all.)

Accessories

Sir / Just this brief note to tell you that I haven't enjoyed such a rib ticklin', tear squeezing, belly laugh in a long time as I did with Mr. Ken Fulton's article on accessories in the Equipment Atlas department of the April 1980 ASTRONOMY. Amen!

P.E. Heflin
Starlight Hill Observatory
Omaha, NE

Star Parties

Sir / I found the article called "You're Looking in the Wrong End, Charlie!" in the May 1980 issue of ASTRONOMY very helpful in reminding me how it was when I first became interested in astronomy. I enjoy star parties, but sometimes find myself getting impatient with people who don't know or appreciate what they are looking at because they expected something like the photographs they've seen. Most, however, have been very interested in what they are seeing and come back for more. Thank you for reminding me that I was once a beginner too!

Donna J. Hughes
Goleta, CA

Ooops...

The photograph of Crux and Centaurus on p. 85 of the June issue should have been credited to David W. Hudgins, not John Sanford.

Robert Goff reports to us that the photo on page 67 of the May issue was taken at Big Bear Solar Observatory (not Sacramento Peak Observatory) on May 22, 1970 at 10:18 a.m. PST. Mr. Goff was then the chief observer at Big Bear and remembers following the development of this region from day to day.

behind
the scenes

the new star dome map

This is the third month ASTRONOMY has carried our new Star Dome. We've had very good response to it; many of you seem to have found it both functional and beautiful. But unless you've used it, you might not have noticed some particularly nice features about it, so I'd like to give you a little background.

We felt that a sky map should look like the night sky — not a road map. Half of the pleasure of stargazing, after all, is looking into that magnificent star-studded dome of the sky crossed by a glowing Milky Way. We didn't want names and words filling the sky, so we designed the map to present them subtly.

Under normal room lighting, at arm's length, the names should just about blend into the sky background. As you bring the Star Dome closer to your eyes, you'll be able to read the major names and constellation lines, then the less important names, Greek letter designations, and finally, the outlines of faint constellations. Under bright light, you'll see coordinates and the ecliptic.

We've plotted about 6,000 stars down to the limit of naked-eye visibility. For stars brighter than the fourth magnitude, spectral types have colors that suggest the real colors. O stars are shown in blue, B in light blue, A as white, F as pale yellow, G as medium yellow, K as light orange, and M in ruddy orange. Deep-sky objects are either bright or typical of their class. With the particular type of map we chose, the southern part of the sky is stretched a bit. You probably won't even notice this in identifying most stars and constellations.

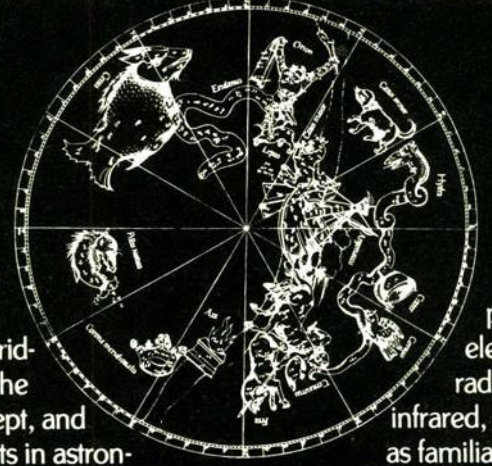
For practical stargazing at night, use a red flashlight with Star Dome. Red is easy on your dark adaptation, and amazing things happen to the map: the background looks jet black, the stars turn white, and names, Greek letters, and constellation lines become much more apparent. Hold it up so the directions (N,S,E,W) on the map correspond to the real directions around the horizon. I like to lie in a comfy lawn chair or flat on my back...well, happy stargazing!

Sincerely,

Richard Berry

Richard Berry

Taking the measure of time and space.



In an engaging blend of science, history, and anecdote, Derek Howse recounts the events that made a London suburb, in a sense, the center of the world. He tells how the Greenwich Meridian came to be the world's Prime Meridian; how Greenwich Time—still the worldwide standard—is found, kept, and distributed; and how developments in astronomy, navigation, and timekeeping have matched increasing speeds of travel.

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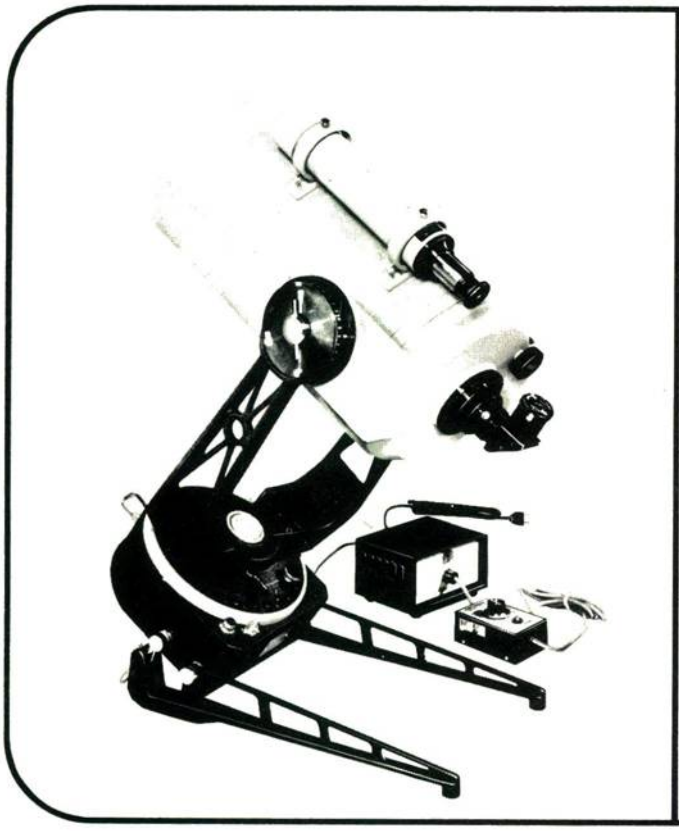

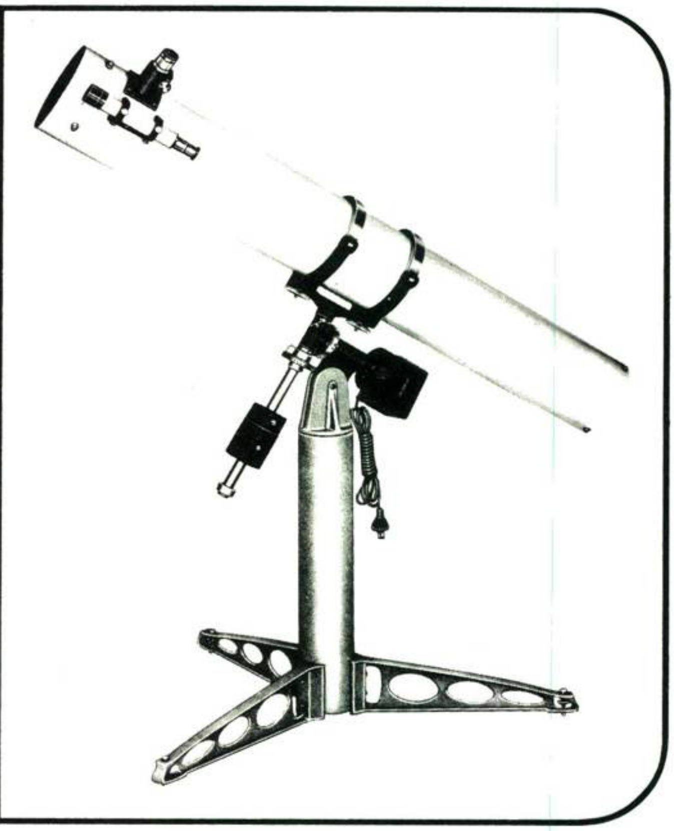

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ASTRONOMY REVIEWS

The Rocket
David Baker
276 pages, hardcover, $17.95
Crown Publishers, Inc. (1978)

Historians have traditionally used some form of technical achievement with which to gauge the intellectual development of a society. David Baker's book *The Rocket* reverses this convention by tracing the social and technical influences which forced many of the major changes in the design and use of reactive-propelled devices. Moving from the rocket's conception as a scientific curiosity of the Han Dynasty in 207 BC to its use today as the booster for the Space Shuttle, this chronology describes the exploits of designers and theoreticians as they react to their nations' internal and foreign affairs.

The text follows precisely the reading plan as given at the beginning of the book. Baker's functional approach to his subject allows the reader to separate historical facts based on scientific considerations from those facts based on political motivation. By organizing the subject in this manner, a whole chapter may be dedicated to a particular scientific idea while the following chapter defines the political philosophy which affected rocket advancement during the same time period.

The most striking example of Baker's practical approach is the section of the book which deals with the parallel developments in the United States, Russia, and Germany during the first half of the twentieth century. Major advancements came from theoreticians such as Konstantin Tsiolkovsky of Russia, and experimenters like Robert Goddard of the U.S. and Hermann Oberth of Germany. All three men foresaw the practical application of the rocket in space travel. Civil unrest caused by anti-Tsar factions in Russia overshadowed Tsiolkovsky's ideas and left his writings unrecognized by the Russian scientific community until after Soviet rule was established in 1917.

Tsiolkovsky's theories hadn't gone unnoticed by Goddard and Oberth; both men experimented with liquid propellants, but as Baker points out only Oberth and his Society for Space Travel (the Verein für Raumschiffahrt) gained wide financial support from the government (German). Goddard, unable to convince high-ranking American military officials of the practical applications of the rocket as a weapon, financed his experiments with limited funds from small scientific organizations.

Oberth and the VfR convinced the aggressive German military of the effectiveness of the rocket as a military weapon. In 1932 the VfR was funded by the German army to do basic rocket research. This acceptance by the German military resulted in the launching of the V2 rocket against England as well as the launching of the careers of noted rocket scientists Wernher von Braun and Helmut Gröttrup. The United States and Russia "solicited" the talents of the German engineers in August of 1945 after recognizing the destructive potential of the V2 as demonstrated against England. From that point on, both the United States and the Soviet Union, with the help of their German engineers, were rivals in the race for military superiority and the scientific quest for space travel.

The remaining chapters of Baker's book deal with the power struggle between the United States and the Soviet Union. Maintaining the thesis of his book, Baker directs his attention to how the growing stockpiles of offensive and defensive weapons led these nations closer to armed conflict. Recognizing the need to maintain a balance of power, both countries signed the SALT 1 agreement in 1972. Although the author's account of the events which transpired during and after the SALT 1 agreement is excellent, he only touches briefly on the causes of the Cuban missile crisis in 1962 which had been the closest we had ever come to war and was therefore a major instigator for the strategic arms limitations talks.

Besides the historical discussions, *The Rocket* offers itself as a reference to those readers interested in the engineering feats of rocket designers. All of the engineering data provided are in metric units. An abundance of photographs is found in each chapter. Handy reference charts and a compendium of launch vehicles allow easy access to pertinent historical and performance data.

David Baker has succeeded in capturing an interesting new approach to history: comparing the rocket with facts derived from internal and foreign policies which influenced its growth. A study of this book should give its reader a better understanding of the complexities which influence this portion of the technical world around him. *Jerry L. Borrer.*

The Amateur Astronomer
Antonin Rükl
John Gribbin, consultant editor
hardcover, 184 pages, $9.95
Mayflower Books (1979)

Just when it seems that all has been said and done to introduce the newcomer to sky watching, another novel idea is implemented and a new book on the subject emerges from press. Such is the case with *The Amateur Astronomer,* a book devoted to explaining complex astronomical ideas in a beautifully graphic text.

Beginning with the preface, the reader is introduced to various commonly used astronomical terms and concepts, and then is briefed on what is known so far about our solar system, galaxy, and the universe in general. All of this information is expanded upon in the pictorial section, the major part of the book, in a quite ingenious way.

The subjects contained in the pictorial section range from the Earth, the atmosphere and its effects on observing, length of day and night, and aurorae, to the Moon, individual planets, asteroids, comets, the Sun, eclipses, stars, nebulae, galaxies, and more. Each topic is treated in a two page (side-by-side) format. A description of the subject concerned is located on the left page, while a beautiful color diagram, painting, or drawing appears on the right page. A description of the illustration can be found in the right margin of the left page, along with suggestions for viewing or photographing, and when the object can best be viewed. At the bottom of the left page are several dates of significance concerning the subject at hand in the history of astronomical discovery.

This format is maintained throughout the pictorial section (135 pages), and proves to be an extremely effective method in teaching basic knowledge about astronomy. Included in this section are nine maps of the Moon, six of which are detailed sectional maps. The text highlights features of the Moon's surface of general interest, while the maps show these features along with the landing sites of lunar probes and examples of every surface feature an amateur may see while viewing the Moon. A map of the lunar far side and diagrams of typical formations are also included.

Several pages of text and diagrams are devoted to the Sun and its features. A map of Mercury, six of Mars, and diagrams of the other planets, meteors, comets, and asteroids round out discussion of the solar system. The subjects of our galaxy, the Milky Way, the brightness, color, distance, diameter, energy, temperature and luminosity of stars, binaries, variables, star clusters, and nebulae, constitute the next portion of the pictorial section. The final topics concern the types of galaxies found in the universe, along with a discussion of the Andromeda Galaxy and Hubble's Law.

The next section of *The Amateur Astronomer* contains nine star maps; six are sections of the sky at 4-hour widths, two are north and south polar views, and one orients you to prominent constellations and stars. The sectional maps go from +55° to –55° declination. The stars are drawn according to magnitude in a "dot" size ratio. The constellations are outlined with bright stars labeled. Prominent objects like nebulae, star clusters, and galaxies are drawn in (according to a key) for identification. The format of this section is similar to the pictorial section. The text lists bright stars, variables, double stars, star clusters, nebulae, and other objects visible in each region of the sky represented by the charts.

A section on planetary phenomena for the years 1979-2000 follows the star maps. These charts show the positions of the five bright planets for each day of the year, their angular distance from the Sun, the constellation each may be found in, and data on conjunctions. The book ends with a discussion on observing techniques, telescopes, and other useful information.

This is not a "run-of-the-mill" book on amateur astronomy but an extremely useful guide to exploring the heavens. It is profusely illustrated with easily understood diagrams and pictures. The text is easy-to-read and very informative. The purpose of the book, as stated in the foreward and preface, is to stimulate a life-time interest in amateur astronomy. *The Amateur Astronomer* certainly fulfills these objectives completely.

It's a book to grow with and to refer back to. Rarely does a book about amateur astronomy so effectively combine both information and illustration in such a complete package. It is highly recommended for all beginners and advanced amateurs alike. *Dan Koehler.*

The Search for Extraterrestrial Intelligence
Philip Morrison *et al.*, eds.
176 pages, paperback, $3
Dover Publications (1979)

SETI, the acronym of the book's title, can be seen either as a colossal waste of time and money, or one of the most important tasks in all of science. Because it requires expensive time on some of the world's largest radio telescopes, the former view often prevails. Yet how fantastic the payoff would be!

This book is a slightly shortened reprint of a NASA work that appeared in 1977 as NASA SP-419. The bulk of the book lies in the "colloquy" reports prepared by various authors who've worked on the problem and here outline the task.

The Big Bang
Joseph Silk
394 pages, hardcover, $8.95
W.H. Freeman (1980)

Subtitled "the creation and evolution of the universe," the book is about just that. It's intended for the non-specialist, but you won't get far in it by casual reading. At the end is a section of mathematical notes (for the determinedly numerate reader), suggestions for further reading, and a glossary.

Practical Astronomy with Your Calculator
Peter Duffett-Smith
129 pages, hardcover, $22.50;
paperback, $7.50
Cambridge University Press (1979)

This simple book shows how anyone having a calculator with log and trig functions can work out for himself such diverse things as: converting right ascension and declination to horizon coordinates (and back again), times of sunrise and sunset, eclipses, planetary positions, etc.

Within its accuracy limitations (generally adequate for most observing), it's a kind of do-it-yourself *Nautical Almanac*. There's a worked example for each type of calculation, and the approach is such that either RPN or algebraic logic machines can be used. The paperback edition is ring-bound to lie flat when open.

Index to the Proceedings of the Lunar and Planetary Science Conferences, 1970 to 1978
Amanda R. Masterson, compiler
261 pages, hardcover, $30
Pergamon Press (1979)

Since their start in 1970, the annual Lunar and Planetary Science Conferences have become an important forum for planetary astronomers to present their results. The published record of the conferences (several thick tomes each) has become a nearly impenetrable jungle: clearly vast and impressive but hard to use. This index is intended to make the access a bit easier; it has keyword, mission, sample number, and author indexes, as well as a title compendium.

Comparative Ephemeris 1980
Roger L. Mansfield
41 pages, paperback, $6
Astronomical Data Service (1979)
[order from publisher at 3922 Leisure Lane, Colorado Springs, CO 80917]

In tabular form, this book presents daily Sun, Moon, and planet positions. The work is in 3 parts: 1) r.a. and dec. for Sun, Moon, and naked-eye planets; 2) geocentric ecliptic positions of Sun and Moon; and 3) heliocentric longitudes of the naked-eye planets.

AstroNews

Currents on Sun Linked to Solar Cycle

Astronomers of the Hale Observatories in California recently obtained results that, according to one of them, "upset all present notions about the nature of the solar activity cycle." Dr. Robert Howard and his co-worker, Dr. Barry J. LaBonte, working from solar data gathered at the Mount Wilson Observatory over the past twelve years, have identified and measured currents of east-west motion at the solar surface. In their patterns of movement, these currents appear directly related to the timing of the eleven-year solar cycle and to the locations of heaviest sunspot activity.

The Sun rotates about its polar axis from east to west. (The solar axis is slightly inclined to the ecliptic.) Because the Sun is a gas throughout, the rotation can differ at different latitudes: the equator rotates once in 25 days, but the polar regions take 33 days. Since 1968, workers at the 150-foot solar tower telescope at Mount Wilson have measured the surface velocity of rotation at all solar latitudes; using a sensitive spectrum analyzer, they measured velocities from the wavelength shifts of an absorption line of iron. After removing the average westward rotation for latitude (in effect, subtracting the velocity of a rotating background), the scientists found zones with extra westward or eastward — fast or slow — motion. It was these east-west currents, which are only about 3 meters per second (7 mph), that Howard and LaBonte studied.

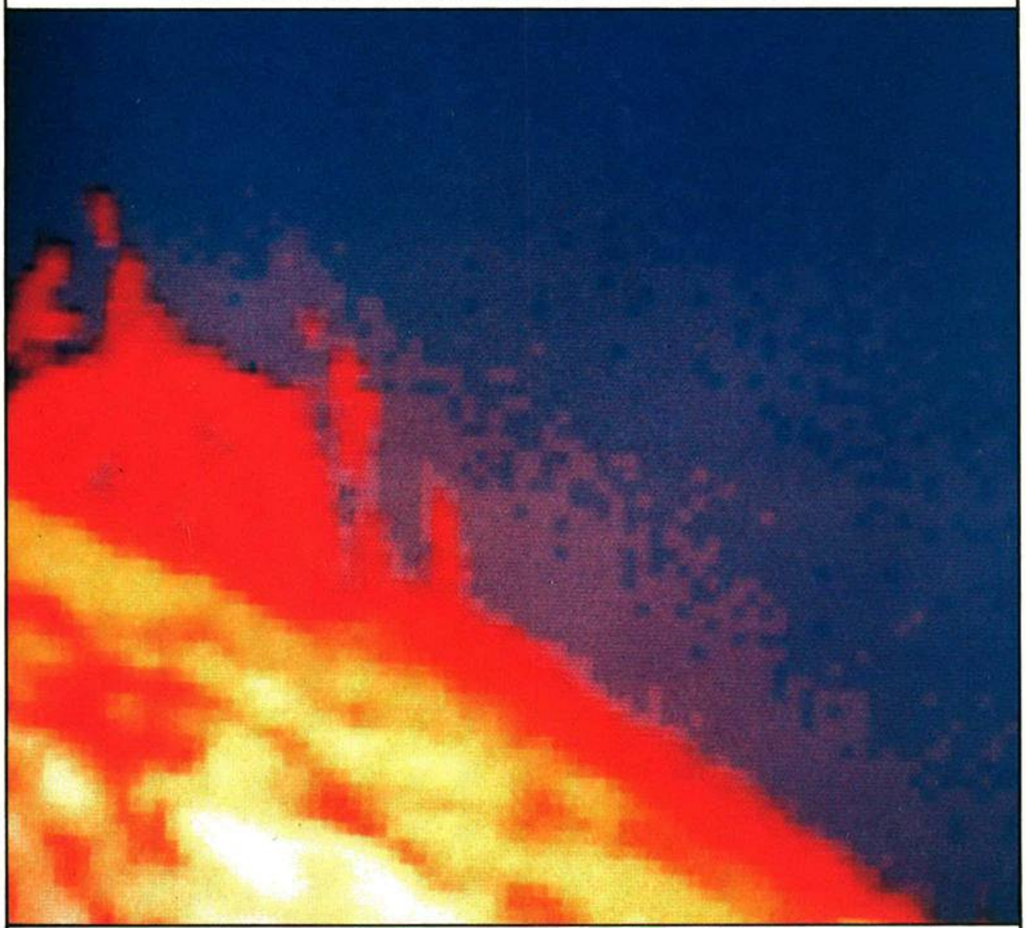
At any time, there are two fast currents and two slow currents in each hemisphere, distributed symmetrically about the solar equator. What is remarkable is that each of these currents gradually migrates toward the equator from year to year. Every eleven years, it seems, a new fast current appears at each pole, to begin a 22-year migration to the equator. The coincidence of this eleven-year cycle and the eleven-year cycle of sunspot and magnetic activity is striking, said the scientists.

Equally intriguing is the relationship between the velocity zones and the places of heaviest sunspot activity, they said. Throughout the twelve years studied, the region of heaviest sunspot activity coincided almost exactly with a boundary zone between fast and slow streams. In effect, the sunspot zone migrated with the currents toward the equator.

The fast and slow currents that will be responsible for the next solar cycle (maximum about 1991) are already seen slowly drifting toward the equator at high solar latitudes. The first sunspots of that cycle will not appear until about eight years from now.

These results evidently represent, according to Howard and LaBonte, "the first evidence of the association of mass motions with large-scale characteristics of the solar activity cycle."

An Ultraviolet Solar Prominence

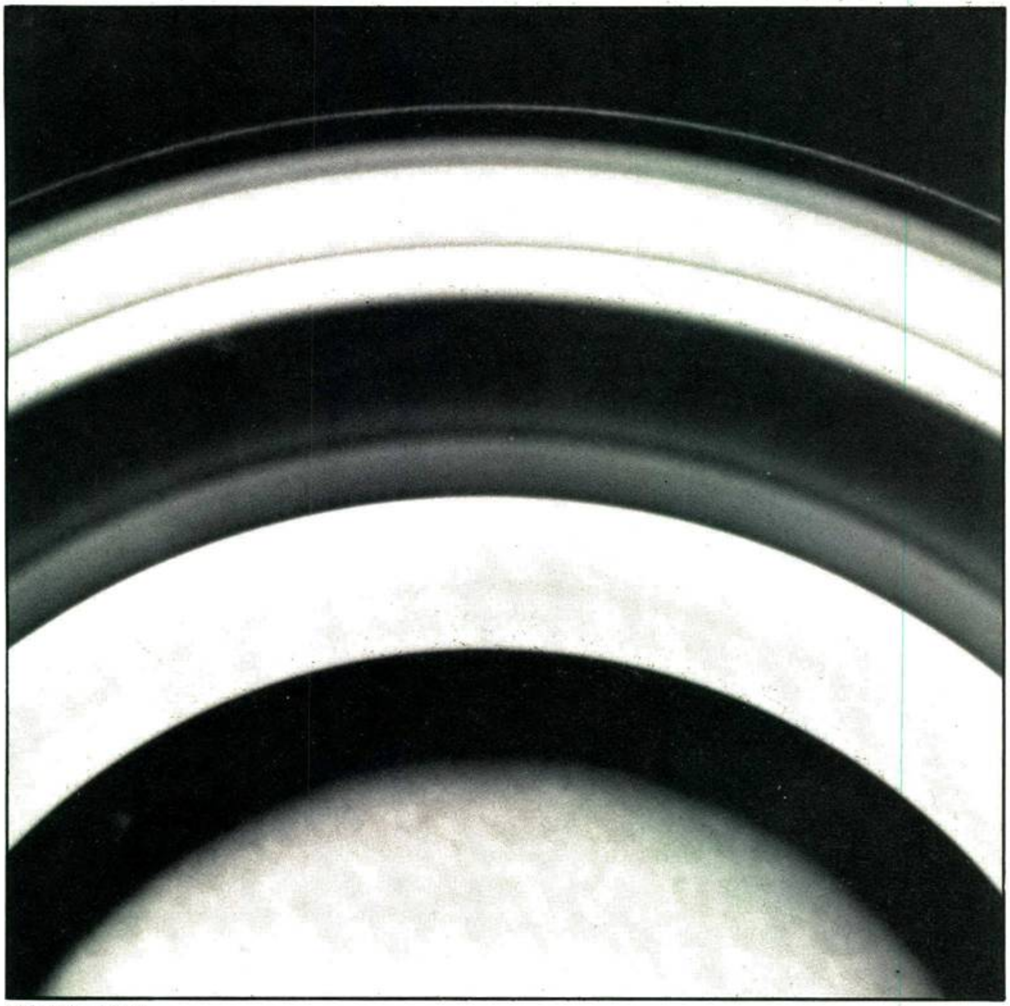


This ultraviolet photograph taken by instruments aboard NASA's Solar Maximum Mission spacecraft is the first high-resolution image returned of a solar prominence — a violent eruption on the surface of the Sun arcing at least 40,000 kilometers (25,000 miles) high. Launched February 16, the Earth-orbiting satellite is the first spacecraft designed specifically to provide scientists with observations of solar flares over a wide band of wavelengths in the ultraviolet, X-ray, and gamma-ray regions of the spectrum (see "Solar Flare Satellite," AstroNews, June 1980). The mission is designed to coincide with the solar maximum period, the peak of the 11-year sunspot cycle when particularly explosive events take place on the Sun's surface. The satellite plays the pivotal role in a coordinated program of spacecraft, sounding rocket, and ground-based observations extending at least through February 1981 (see "Solar Maximum Prompts Intense Study of Sun," AstroNews, January 1980). The mission, managed by NASA's Goddard Space Flight Center in Greenbelt, Maryland, represents a major step toward understanding the violent nature of the Sun and its effects on Earth. NASA/JPL photo

Since the movements are identical in both northern and southern hemispheres, we are seeing a "large-scale, deep-seated phenomenon." The velocity bands must be associated in some fundamental way with the subsurface magnetic fields responsible for the solar cycle. Presumably, the subsurface fields responsible for the next solar cycle have already formed at high latitudes.

Up to this time, scientists have had few clues to help in unraveling the puzzle of the solar activity cycle. The results of Howard and LaBonte now provide evidence that the Sun has a strong internal dynamo generating the magnetic fields that form the sunspots and other features of the solar cycle.

Howard has been a staff member of Hale Observatories since 1961; LaBonte came in summer 1978 as a research fellow. Their discoveries, which rest upon more than a decade of solar observations, show once again the significance of long-term support of research in the work of institutions like Hale. Long-term funding of the work of Howard and LaBonte has been from the National Science Foundation, NASA, and the Office of Naval Research.



NASA/Ames photo

A Pioneer to Saturn's Rings

The computer representation of Saturn's rings seen above (and in color on this month's cover) shows many details of the planet's ring structure and composition never seen before.

This is not a photograph, but instead shows ring data taken at 6° above the plane of the rings as though it were seen from one million kilometers (620,000 miles) above the rings (or directly over Saturn's north pole). The display shows light which came in from the Sun at 2° below Saturn's ring plane, was reflected through the rings and back out to the spacecraft at 6° above the ring plane. (Sunlight reflected through the rings and then upward at a 90° angle might well look different than this.) Ring bands as small as 500 kilometers (310 miles) can be distinguished. The area occupied by the planet has been filled by a randomly selected portion of a Saturn cloud top picture.

The Pioneer spacecraft saw the rings from their dark or unlit side, and measurements of the amount of sunlight which has passed through the rings allow calculation of the amounts of material in the rings and their structure. In general, the brighter a ring looks from its dark side, the less material it contains because light can reflect easily through a thin ring.

The area closest to Saturn is dark because it's devoid of material. Next out from the planet, the broad band of the C ring is very bright, and hence contains little material. The B ring is almost completely black because no sunlight can pass through its dense ring material. The narrow bright band outside the B ring is Cassini's Division, which actually contains about the same amount of material as the C ring. From Earth (on the lit side of the rings) Cassini's Division looks empty. Next, the outer A ring shows varying brightness, indicating that it contains varying amounts of material. The A ring's outer edge is dark because it contains virtually no material; the inner edge is dark because of dense ring material there. This is shown by Earth observations as well as Pioneer polarization measurements, made on the rings' lit side. The new F ring, discovered by Pioneer, is the outermost thin line.

The many detailed variations within the individual rings provide entirely new information about ring structure (the orbits and distribution of ring particles circling Saturn). Light intensity data for this graphic came from two pictures, the close-up of the rings from 943,000 kilometers (585,950 miles), and the best Pioneer view of portions of the inner C ring not included in the former photo.

A combination of all Pioneer Saturn measurements plus all other sources suggests that the thickness of the rings is just under a mile (1.5 kilometers). Scientists now believe that ring particles probably come in a range of sizes, but the characteristic size may be in the neighborhood of 50 meters (165 feet). Pioneer measurements of ring mass showed the A and B rings to have a very low density, indicating that they are largely ices.

Index

- Currents on Sun Linked to Solar Cycle
- An Ultraviolet Solar Prominence
- A Pioneer to Saturn's Rings
- Planning for Spacelab
- Another Jovian Moon
- More Telescope for Less

AstroNews

Saturn's rings, one of the great spectacles of the solar system, were discovered by Galileo in 1610. The rings range outward about 77,000 kilometers (48,000 miles) from Saturn's cloud tops. The total width of the three visible rings is 64,800 kilometers (40,300 miles). The rings are believed to be either the remains of a broken-up moon or, more likely, a mass of orbiting material prevented from forming into a moon by Saturn's gravity.

Planning for Spacelab

The Spacelab is to be a major element of the NASA Space Transportation System being developed to transport people and material economically and routinely between the ground and Earth orbit. With facilities and equipment similar to laboratories on Earth but adapted for zero gravity, the Spacelab will be transported aboard the NASA Space Shuttle Orbiter for Earth-orbital missions lasting 7 to 30 days, providing an orbital research center for both astronauts and scientists. Unlike its predecessor, Skylab, this new system won't be left in space unattended. It will remain in the Shuttle for the duration of its mission, and be returned to Earth for refurbishment and preparation for the next mission.

In any of several configurations to meet specific experiment requirements, it will provide a shirt-sleeve environment, like that in a passenger airliner, for scientific and technical experimenters, both male and female. One to four payload specialists can be accommodated on each flight. They will eat and sleep in the Orbiter. On return to Earth, the Spacelab will be removed from the Orbiter and outfitted for its next flight assignment.

NASA has signed a $183,960,000 contract calling for the manufacture and delivery in 1984 of a second Spacelab by the European Space Agency. The first Spacelab is already being designed and built in Europe for delivery in time to be aboard an early operational flight of the U.S. Space Shuttle in late 1982.

Funding for development of the Spacelab concept and manufacture of the first flight unit is provided by European Space Agency member nations and is estimated to exceed $850 million. In return for the contribution by the European Space Agency of the first flight unit, NASA agreed to procure from the European agency a second flight unit and others if needed in the future.

The second Spacelab, like the first, will be built by the ERNO industrial facility in Bremen, Germany, prime contractor to the European Space Agency. At least 26 subcontractors, in the European Space Agency member nations of Germany, France, Italy, the United Kingdom, Spain, Belgium, the Netherlands, Switzerland, Austria and Denmark, as well as in the United States, are expected to be involved in producing components and subassemblies of the second Spacelab.

NASA and the European Space Agency have also selected 37 experiments to be conducted on the first flight of Spacelab. The 37 experiments chosen fall into five broad categories: atmospheric physics and Earth observations; space plasma physics; material sciences and technology; astronomy and solar physics; and the life sciences. Thirteen are sponsored by NASA, and the remainder are the responsibility of the European Space Agency. The Spacelab 1 mission is to be conducted jointly by the two agencies. NASA will furnish the Space Shuttle and will manage in-orbit science activities.

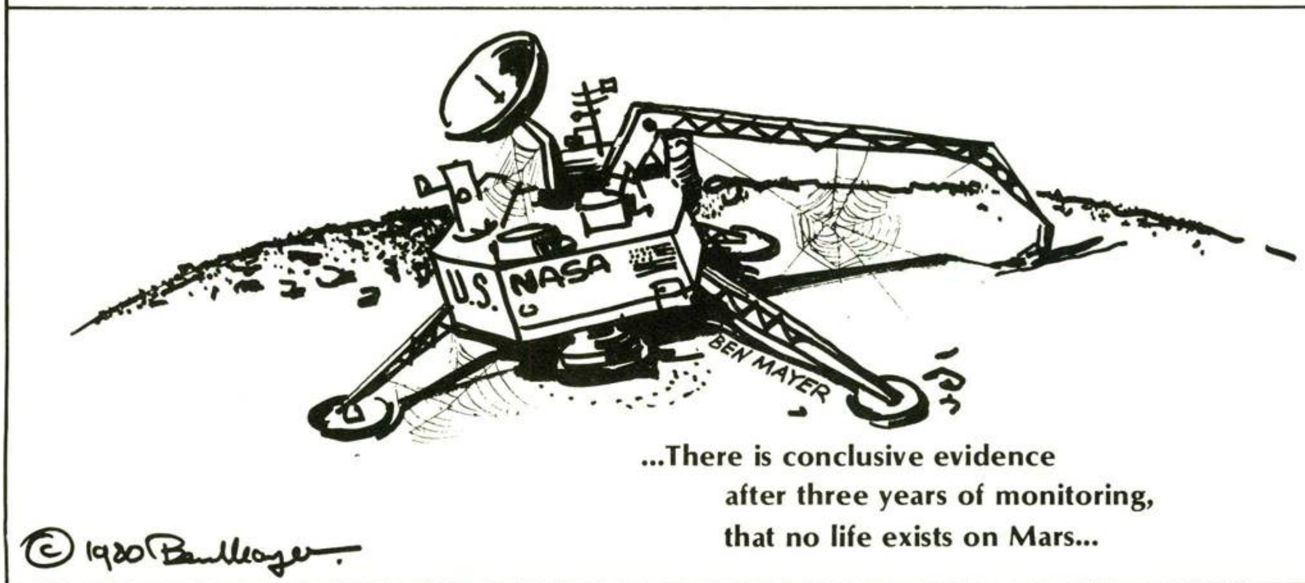
Dr. Thomas A. Mutch, NASA associate administrator for Space Science, announced the selected NASA-sponsored experiments in letters to the experiment developers, who are called principal investigators. The selection of experiments for the flight was made from a list of experiments identified several years ago for definition and development. Three NASA-sponsored experiments and a major European Space Agency facility that were under development had to be deferred, and will be assigned to subsequent Spacelab flights. According to Spacelab 1 Mission Manager, Robert E. Pace, at NASA's Marshall Space Flight Center in Huntsville, Alabama, the major limiting factor that prevented the selection of all developed experiments was mass. Each agency will be able to fly 3,062 lbs. (1392 kg) of experiment equipment on the mission.

Among the experiments chosen are an imaging spectroscopic observatory, a study of astronomical X-ray spectroscopy, measurements of the solar constant, and a measurement of heavy cosmic ray isotopes.

Unique non-astronaut science crew members, called Payload Specialists, will conduct the experiments in space. Five Payload Specialists, two Americans and three Europeans, are now training for the first mission. Two of this group, an American and a European, will fly aboard Spacelab 1. The other three will operate ground-based experiment equipment and assist the pair in orbit.

Operation of the Spacelab will be a United States responsibility with the NASA Johnson Space Center, Houston, Texas, in charge of flight operations and the NASA Kennedy Space Center, Florida, responsible for the launching of the combined Spacelab and Space Shuttle.

The Spacelab program lays a basis for greatly expanded international cooperation in space. NASA and the European Space Agency are making known the benefits and future availability of Spacelab to other potential users in the international community.



...There is conclusive evidence after three years of monitoring, that no life exists on Mars...

NASA photo.

Another Jovian Moon

A scientist at the Jet Propulsion Laboratory, Pasadena, CA, has discovered a new moon of Jupiter — its 15th — while searching through pictures taken by NASA's Voyager spacecraft.

The new satellite, tentatively called 1979 J2, was found by Dr. Stephen P. Synnott of the Voyager Optical Navigation Team. The pictures were taken by Voyager 1 about 4½ hours before the spacecraft made its closest approach to Jupiter on March 5, 1979.

The new Moon, the second discovered from Voyager photographs, is estimated to be 70 to 80 kilometers (43 to 50 miles) in diameter. It orbits the planet every 16 hours 16 minutes, at a distance of 151,000 km (93,900 miles) above Jupiter's cloud tops — between orbits of the satellites Amalthea and Io.

Dr. Synnott was searching Voyager 1 images to confirm the existence and orbit of the other new satellite, 1979 J1, discovered last October, when he noticed a shadow sweeping across the face of Jupiter where no shadow should have been.

Synnott was able to predict the orbit of the satellite from two shadow observations which allowed him to find evidence of the satellite in seven earlier images.

Synnott also confirmed the discovery of 1979 J1 that was made in October 1979 from photographs taken July 8, 1979 by Voyager 2. That moon orbits Jupiter at a distance of 57,000 km (36,000 miles) above the clouds.

Satellite 1979 J1 was estimated to be 30 to 40 km (19 to 25 miles) in diameter. It makes one orbit of Jupiter every 7 hours 8 minutes. Some scientists believe 1979 J1 could be a source for much of the fine dust that makes up the Jupiter ring discovered by Voyager.

The two Voyager spacecraft are en route to Saturn after their successful encounters with Jupiter last year. Voyager 1 will make its closest approach to the ringed planet on Nov. 12, 1980. Voyager 2 will fly past Saturn on August 26, 1981. The latter spacecraft will then continue on to an encounter with Uranus — about a billion miles farther away — in January 1986.

The Voyager project is managed by the Jet Propulsion Laboratory, a government-owned facility managed for NASA by the California Institute of Technology.

More Telescope for Less

Using a ten-year accumulation of spare parts, a priority on staff time, and about $28,000 for additional materials and fabrication, Lick Observatory has produced and installed a new 40-inch telescope worth close to $750,000 at its Mount Hamilton Observing Station.

"Although this project was done with an incredibly frugal budget," said Lick Director Donald Osterbrock, "our group has produced a telescope of excellent quality with one of the most advanced electronic systems in use today."

The system, pioneered at Lick for its 120-inch telescope, uses an image-tube scanner to collect light and "print" it out through a microprocessing computer. The system also includes a television camera that tracks the movement of an object across the heavens and keeps it centered in the telescope's mirror.

"Because both the new 40-inch and the 120-inch Shane telescope use similar systems," said Osterbrock, "any planned additions for the larger instrument can first be tried and tested on the smaller one. And that alone will save us from very expensive downtime on the 120-inch."

Creation of the new, modern instrument, which successfully took its first spectrum in early December of 1979, will take pressure off the use of the 120-inch, noted Osterbrock. "It is particularly good for our graduate students and postdoctoral fellows who could not get time on the 120. Now they can do high-quality research on the 40-inch," he said.

A number of research projects do not require the use of Lick's large 120-inch instrument, but until now there was no alternative.

Parts for the telescope came in large measure from Lick warehouses, according to David Rank, the Lick faculty member who worked with engineer Jack Osborne in pushing the project to completion. "The 40-inch mirror was ground in our shop several years ago as a possible replacement for another telescope on the mountain. But the quality of the finished product delivered by optician Howard Cowan was so good that it inspired us to start building a whole new scope around it," said Rank.

Back rooms were scoured for spare metal parts and raw material already on hand and a building team was formed by Rank, Osborne, and Neal Jern, the Lick shop superintendent. The new instrument had to be designed with two restrictions: It could use only parts that could be readily fabricated on Lick machinery and the completed instrument had to fit into an existing 24-foot dome on Mount Hamilton.

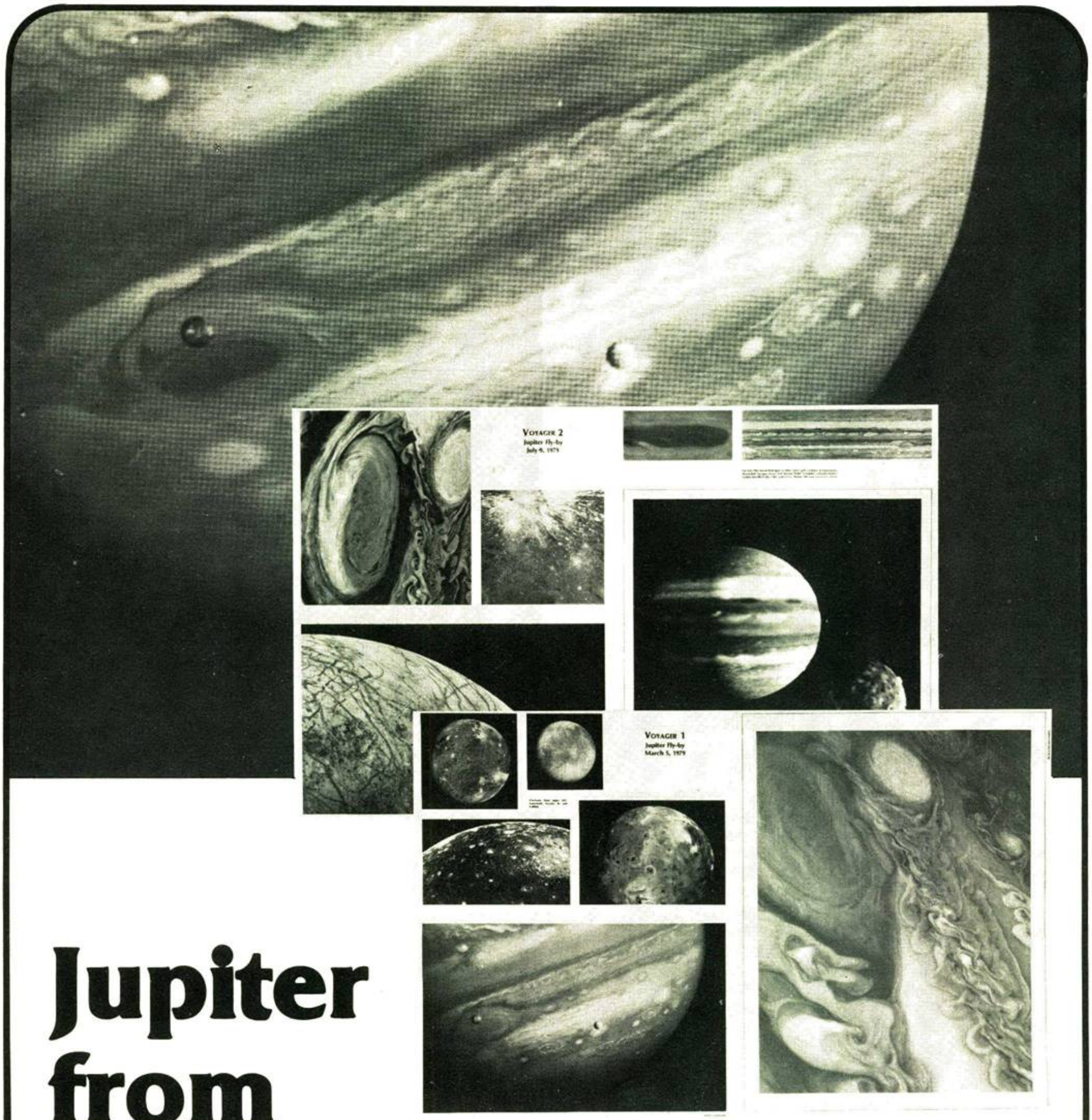
"Innovation was the key word for this project," said Rank. "One way we cut corners without losing quality was to use newly developed friction drives rather than costly precision gear drives to move the mirror housing and yoke. Instead of spending $12,000, we spent $600, and had an improved system as a result."

In another money-saving move, the shop built its own electronic equipment and television set to track stars, and managed to incorporate in the design a spectrograph that was already available. That piece of equipment is on permanent loan from the University of California - San Diego campus, which had originally been given it by the U.S. Air Force.

The dome into which the 40-inch telescope has been set was rebuilt for its new duties. 25-foot steel pilings had to be extended to bedrock to support the 4½-ton instrument and the dome itself was fitted with an electronic position reader. That way all movement could be remotely controlled from a next-door "read-out" room where most of the electronic gear is housed.

In addition to the challenge of building an in-house telescope "from scratch," the Lick team was inspired by a gift to the observatory from the late Anna L. Nickel of San Francisco. She had left 40% of her modest estate "for the improvement of operation of the Lick Observatory" and that amounted to $53,000 by the time the Lick office received the bequest in 1976.

"Through her gift, Anna Nickel has helped Lick Observatory, the University of California, and astronomy," Osterbrock said, "and we will always remember her."



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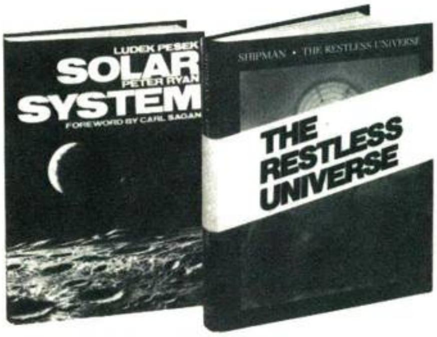

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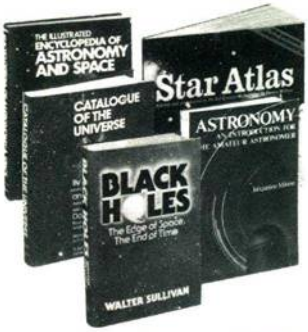
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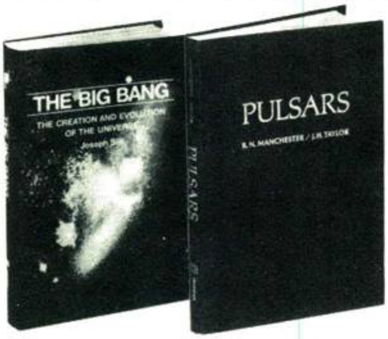
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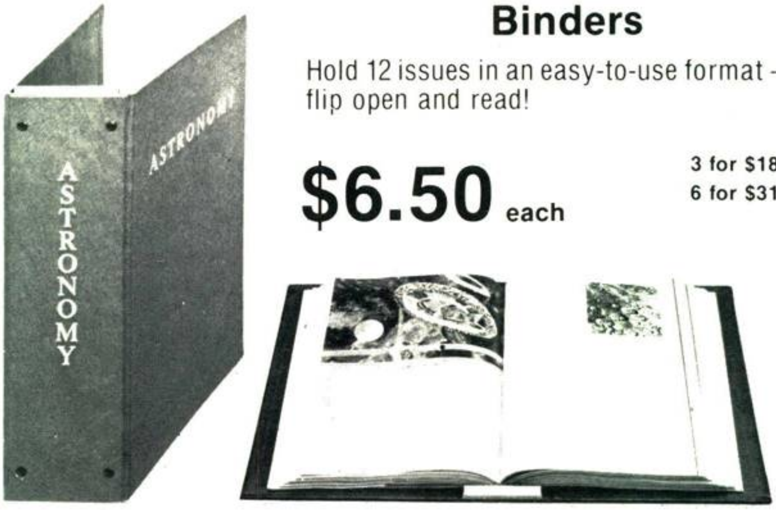

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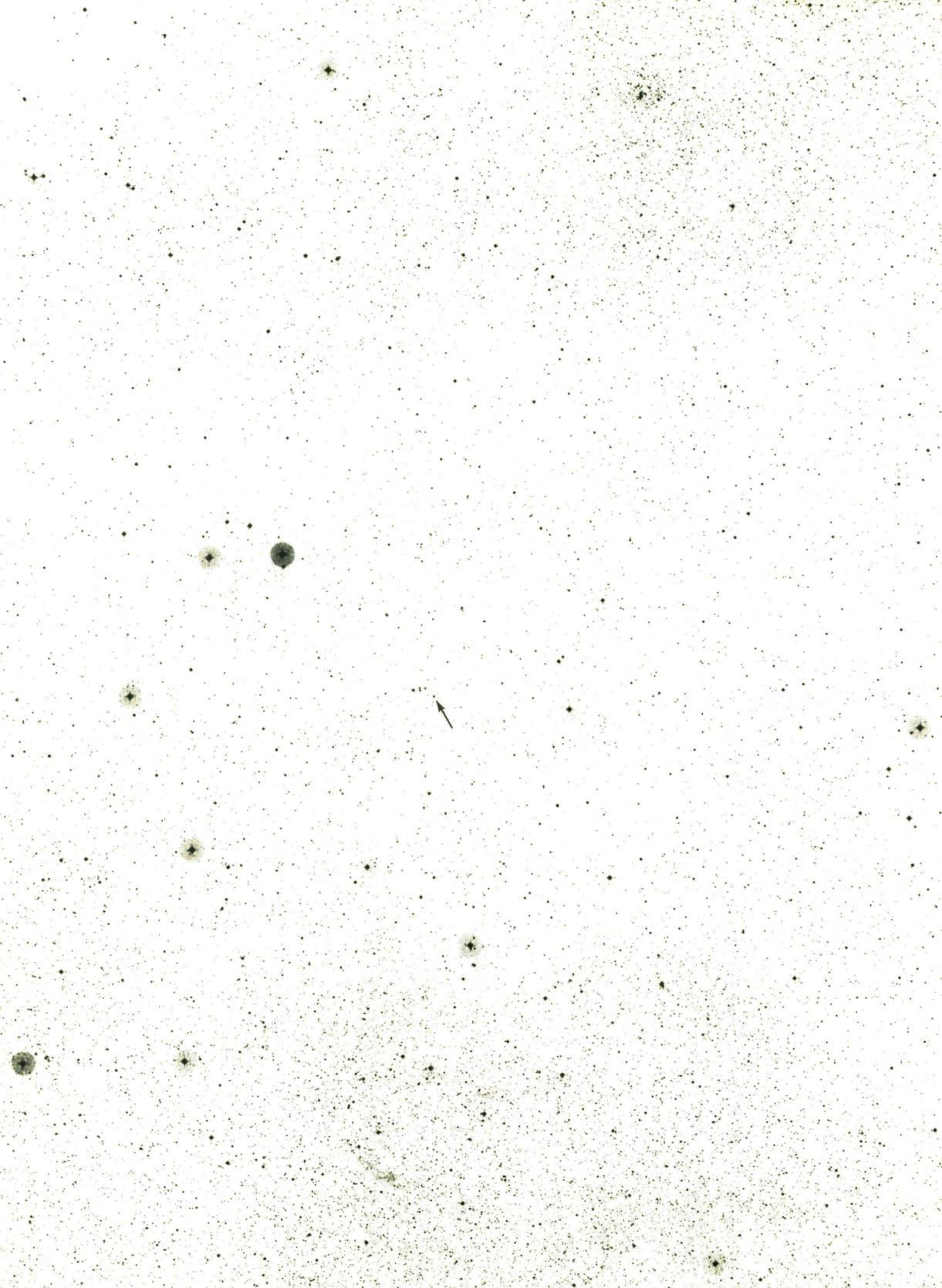


SS-433

by
Joel Davis

Buried among myriad faint stars in the constellation Aquila is a reddish 14th magnitude star with bright hydrogen emission lines in its spectrum. This dim red star was the 433rd object listed in a catalog of newly-observed stars having bright hydrogen emission lines in their spectra which was compiled by C. Bruce Stephenson and Nicholas Sanduleak of Case Western University, and so it is known as Stephenson-Sanduleak 433, or simply SS-433. Its coordinates are right ascension $19^h 09^m 21^s$, declination +4°53′.9 (1950). There the matter rested for more than a decade.

But now SS-433 is the subject of intense debate among astronomers and astrophysicists. What makes this little red star so important? Why have astronomers from all over the world suddenly grown interested in it? What do they suspect: A supermassive black hole? A supernova remnant? An X-ray binary? Or perhaps something altogether new and strange? New data on SS-433 are still being gathered almost daily, and new models to explain the data appear nearly as frequently. No one involved in the puzzle of SS-433 is sure when the pieces will finally fall together — or indeed if they ever will. Certainly something very strange is going on in Aquila.

The story continued in 1975. SS-433 was spotted again and new coordinates published for it (unfortunately, the coordinates were wrong). Then in 1976 F.D. Seward and three associates noted the existence of a weak X-ray source in Aquila identified by the British Ariel 5 X-ray satellite and labeled A1909+04. It appeared to have about the same coordinates as the X-ray sources H1908+050 (examined by the HEAO satellites) and 4U 1908+05 (observed by the Uhuru X-ray satellite). The following year (1977) David Clark, with A. J. Green and J. L. Caswell, pointed out the existence of a variable but unresolved radio source in Aquila in about the same general location, and other astronomers found a supernova remnant in Aquila which was given the identification number W50. That same year Stephenson and Sanduleak published the results of their earlier search in a supplemental volume of the *Astrophysical Journal*. All of these observations were good, solid, ordinary — and largely unconnected. The connections began to be made in 1978.

SS-433 is marked by the arrow in this photograph taken with the Palomar 48-inch Schmidt telescope. At top and bottom the faint filaments of the possible supernova remnant W50 are visible in this negative print. Photograph courtesy of Sidney van den Bergh, Dominion Astrophysical Observatory, Victoria, B.C.

David Clark, this time with Australian astronomer Paul Murdin, first connected the optical object SS-433 with the radio source he had spotted with Green and Caswell in 1975. Clark and Murdin wondered if SS-433 could also be physically connected with the supernova remnant W50. (That supernova remnant — if that's what it really is — has been given an age of about 40,000 years, though it could be younger.) What's more, they noted the apparent connection between SS-433 and the X-ray source A1909+04.

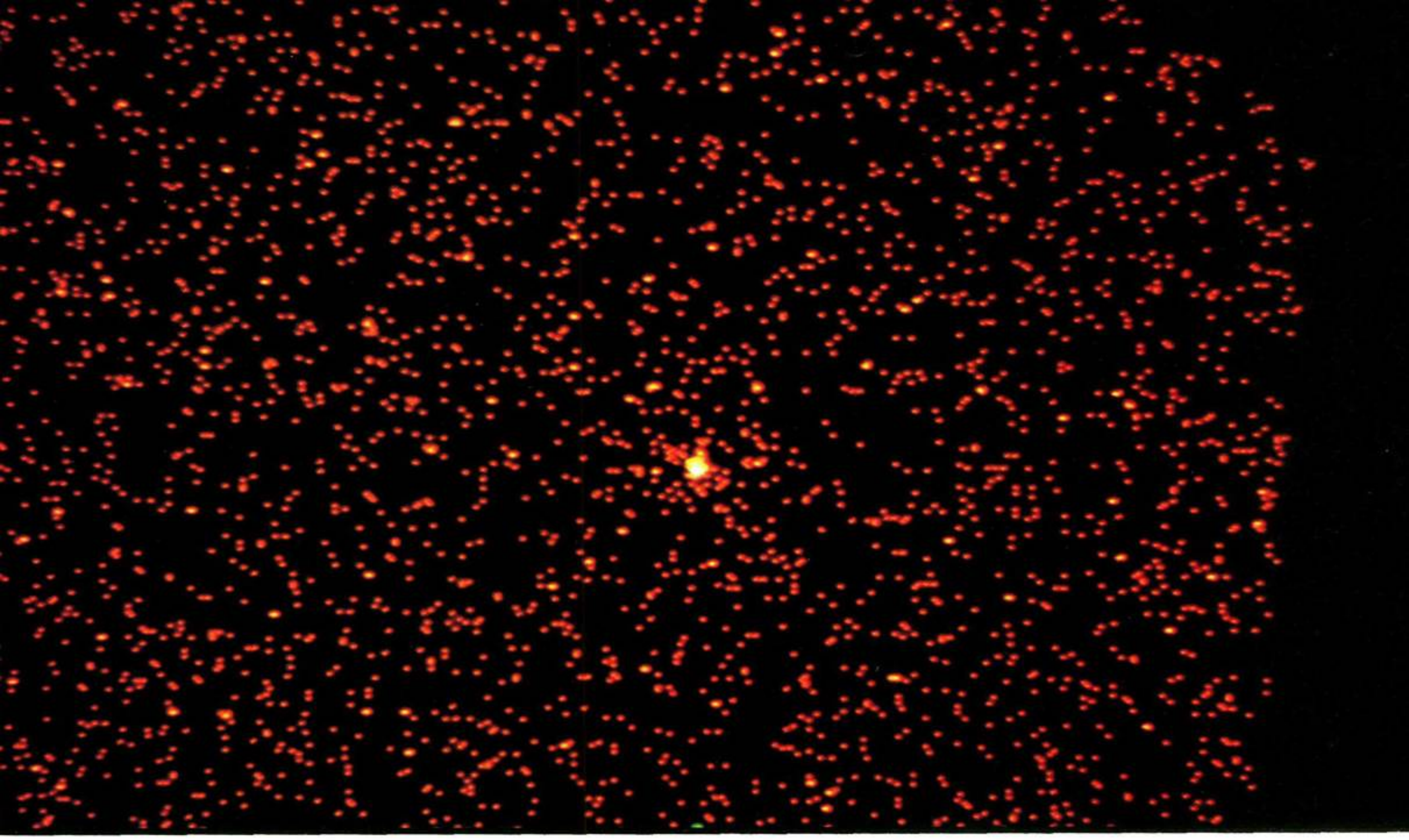
The two proceeded to take the first modern spectrum of SS-433. They noticed nothing extraordinary about it at the time, but never doubted the need to get a spectrum of the object. It was the optical counterpart of an X-ray source and such things are always "hot topics" in astrophysics.

Bruce Margon was interested in what Clark and Murdin were doing. "Part of my research program involves making optical ground-based spectroscopic and photometric observations of the visible counterparts of galactic X-ray sources," explained the member of the Department of Astronomy at UCLA. "I've been doing that for years. So once Clark and Murdin suggested, 'Hey, here's a new optical counterpart of an X-ray source,' I decided I would take a few spectra to confirm their work."

Margon added that it wasn't a difficult task. Although fourteenth magnitude, "It's a very bright star by our standards, so it was just a ten-minute job. I decided to take one or two spectra to see what it looked like with our equipment, really intending merely to confirm Clark's and Murdin's work."

Margon and his associates (Holland Ford, Jonathan Katz, Karen Kwitter, and Roger Ulrich of UCLA, and Remington Stone and Arnold Klemola of the UC Santa Cruz Lick Observatory) began taking spectra on August 2, 1978. And with that, SS-433's career as nothing more than a faint, reddish, somewhat peculiar 14th magnitude star ended.

The spectrum of SS-433 contained the usual emission lines of ionized nitrogen, carbon and helium, which was not too surprising for an X-ray source. These lines are often the



The orbiting Einstein Observatory took the above X-ray picture of SS-433 with its High Resolution Imager. The field of view is about 25 minutes of arc, and the central source, less than 5 seconds of arc in extent, appears as the unresolved yellow dot in the center. Photograph courtesy of Ernest Seaquist, David Dunlap Observatory, University of Toronto.

"signature" of such things. However, there were three other sets of neutral lines that were completely incredible. SS-433 had, it seemed, unidentified emission lines that were moving, shifting along the spectrum on a nightly basis and by enormous amounts. The shifts were so huge that Margon at first wondered if his equipment was broken.

Astronomers almost instinctively attribute moving spectral lines to the Doppler effect. A stellar object moving away from the observer has lines shifted toward the red end of the spectrum, and an object moving toward the observer has lines shifted toward the blue end.

SS-433, though, had emission lines with both blue shifts and red shifts at the same time, continuously. Margon and his associates were looking at data that seemed to say SS-433 was moving in two directions at once, with a combined velocity of nearly 50,000 kilometers per second — 15% of the speed of light. Such velocities have been observed in quasars, but quasars are objects far beyond our own Galaxy, at the edge of the observable universe. Examination of interstellar absorption lines in the object's spectrum showed SS-433 was only about 11,000 light-years from Earth, well inside our Galaxy. It was certainly no quasar.

Margon announced his findings at the Texas Symposium on Relativistic Astrophysics in December 1978 and threw everyone into an uproar. SS-433's behavior was unique and unprecedented. At that time the Sun was occulting the object so no new observations could begin until March 1979, but that didn't stop the speculation about what caused SS-433's strange behavior.

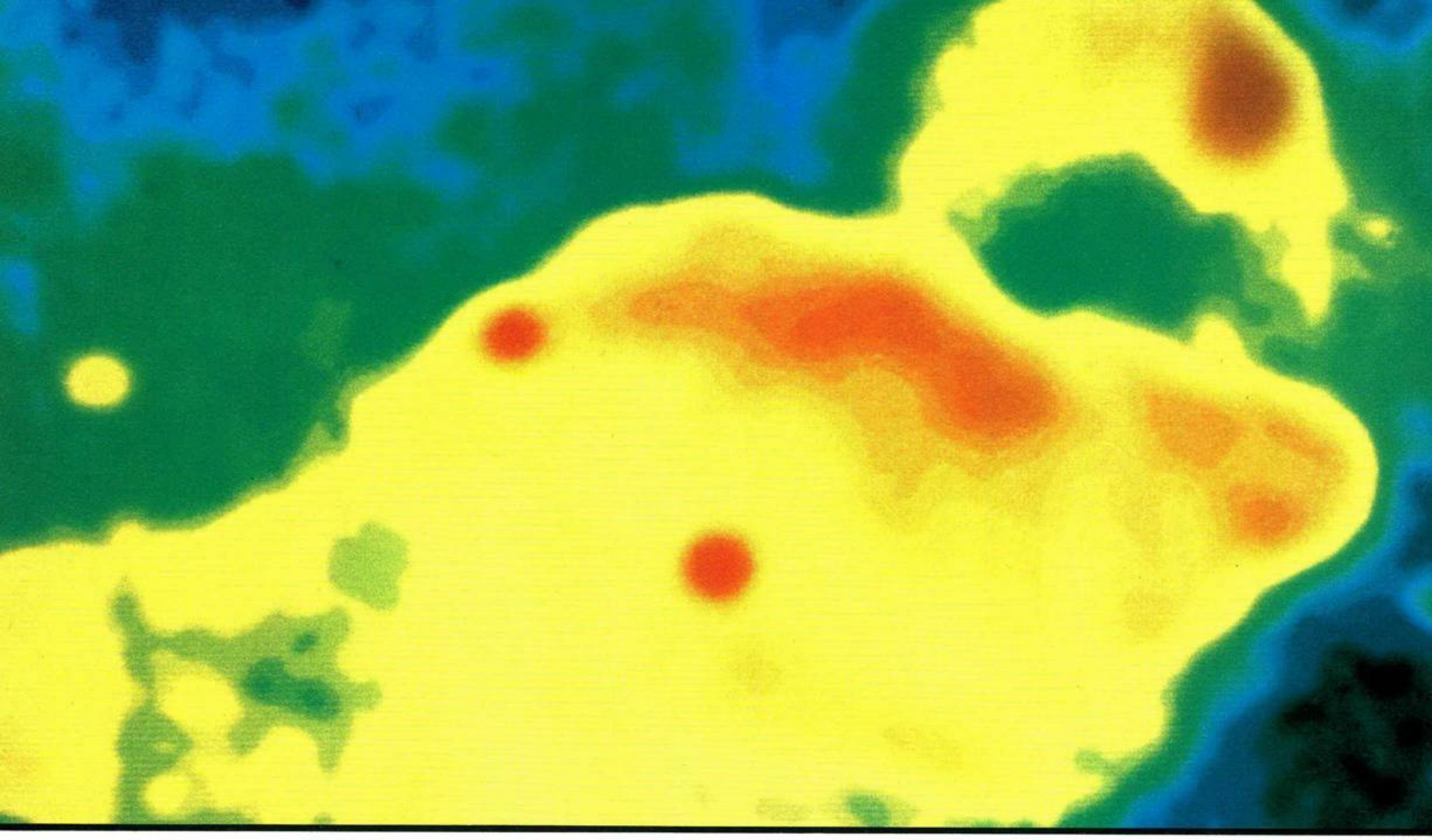
Andrew Fabian and Martin Rees suggested that the Doppler shifts in the spectrum were caused by two jets of matter spraying out of SS-433, one toward Earth causing the blue shift, and one away from Earth causing the red shift. As the velocity of the jets changed, the movement of the lines in the spectrum varied. The "jet of matter" phenomenon had been observed in quasars, and while no one seriously thought SS-433 was a quasar, perhaps it was acting like one.

In March 1979 the SS-433 observing season began again, and since then an enormous amount of data has been accumulated on SS-433. Bruce Margon now has a record of the object's spectrum for practically every night, plus the numerous observations of other astronomers. All this has produced a wealth of precise information on the behavior of SS-433.

For one thing, the moving emission lines have now been identified. They include the Balmer lines at 6563 A and 4861 A (the hydrogen-alpha and beta lines), and the helium I line at 6678 A. These three neutral emission lines are triple-shifted, with a stationary component, a blue-shifted component, and a red-shifted component. Other lines identified include the Balmer hydrogen-gamma line at 4340 A and a helium I line at 5876 A. What's more, the movements of the lines are without a doubt periodic, with a 164-day cycle.

At first glance, that finding made a binary system model for SS-433 seem quite reasonable: the spectral lines shifted as the two objects in the system orbited around each other. The problem was the specifications on that binary system. To cause Doppler shifts as huge as those seen, it would have to be a system with two black holes having a combined mass of a billion suns, orbiting one another at 50,000 kilometers per second with a 164-day cycle. Such a system was flatly impossible. The gravitational effects would visibly warp space-time around the binary and even distort the structure of the galaxy in its vicinity. Furthermore, the moving spectral lines were in phase, and a billion-solar-mass black hole binary wouldn't show that. Light would take so long to move across the system that the lines would be out of phase.

Several other scientists proposed models featuring black holes, but with a different slant. In these models, matter spiraling into an accretion disk around a single black hole would produce the moving emission lines. Depending on the particular model, the black hole had a mass of either



The "supernova remnant" W50 is shown above at radio wavelengths. The color scheme is such that regions of greater radio brightness are progressively redder. SS-433 is the red spot in the middle of W50, while the spot at upper left is probably a background extragalactic source. The arc at upper right is the ionized hydrogen region S74. This image was produced by B.J. Geldzahler, T. Pauls, and C. J. Salter using the 100-meter radio telescope of the Max Planck Institute for Radioastronomy at Effelsberg in West Germany.

300,000 suns or 1,000,000 suns. Yet these models, too, had problems, and R. J. Terlevich of the Institute of Astronomy in Britain (one of its originators), pointed one out. The accretion disk would have to be very narrow to cause the observed effects, and viscosity effects in the disk would inevitably spread it out. Perhaps the emissions came from the densest part of the ring, Terlevich suggested, or possibly a planetary-size body was spiraling in and accreting. Were that the case, an orbital period of about one hour would be detectable.

No such period has yet been found in SS-433, though, and this particular model has not found much acceptance.

Bruce Margon and George Abell of UCLA found some value in the earlier model of Fabian and Rees, however, as well as in a suggestion of Mordehai Milgrom of Israel. The two have come up with the so-called "kinematic model" as a result, and it is so far the most widely accepted explanation of the behavior of SS-433, although it doesn't specify the nature of the central power source.

In the kinematic model, an unidentified object (or objects) is ejecting two oppositely-directed beams of matter along an axis (possibly magnetic) inclined to a second axis of precession. As a result of precession around this second axis, the jets sweep around the sky with a period of 164 days. This neatly explains the Doppler shifts and the periodicity. The kinematic model is also a geometric one in which the exact angles are specified. The axis of the twin beams, each moving at about 80,000 kilometers per second, is inclined to the second axis of precession by about 17°; and this axis is inclined at 78° to observers on Earth. As the gas streams out it finally reaches a distance where it cools enough to recombine and cause the observed emission lines. The stationary lines come from low-velocity gas near the object.

The kinematic model could be used to make a specific prediction about the future behavior of SS-433. Margon and Abell said the moving lines would cross around the first of July 1979, separate for about 40 days, and then merge and separate again. With his night-by-night record of its behavior, Margon was able to observe exactly that.

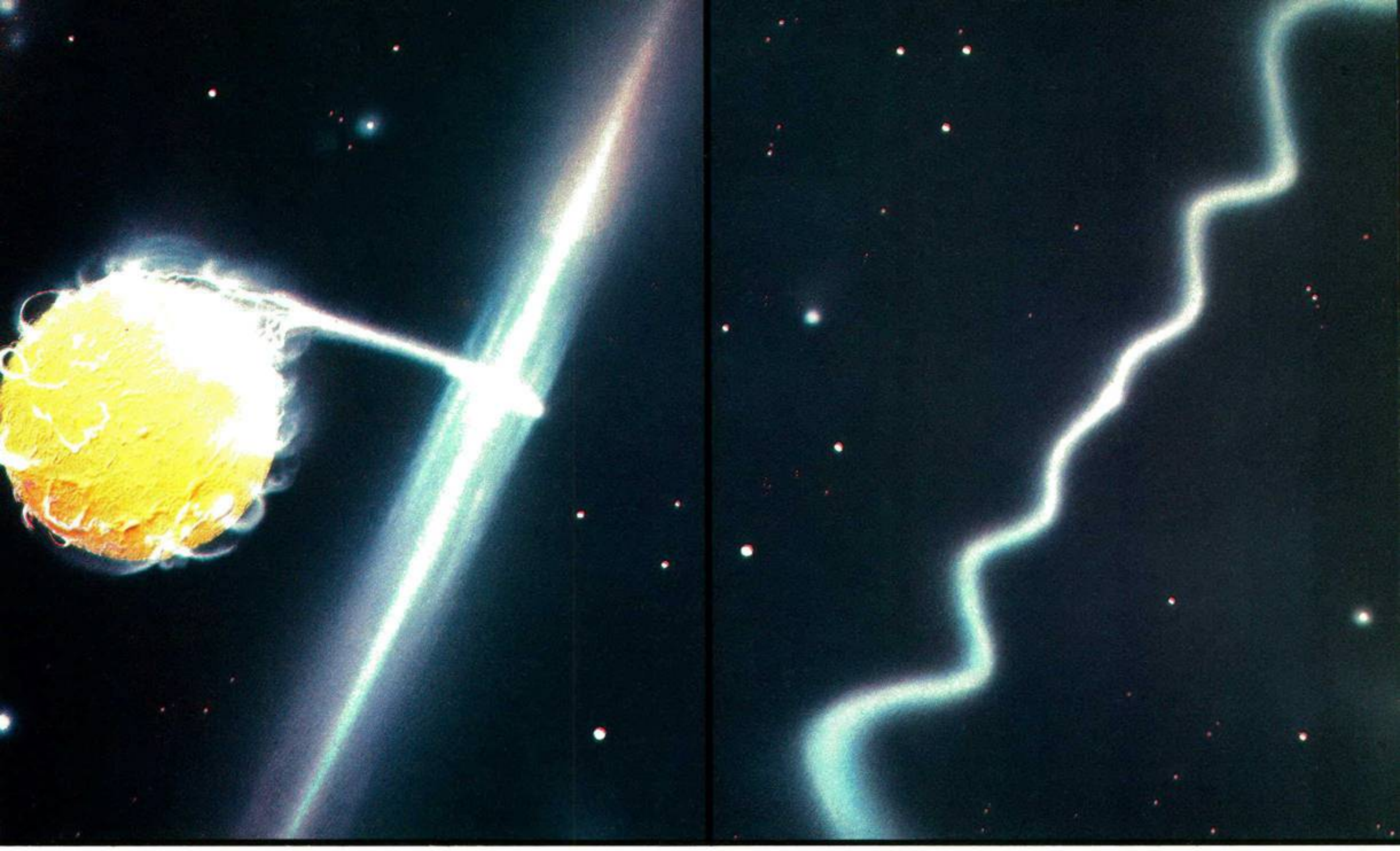
Meanwhile, Margon's associate at UCLA, Jonathan Katz, had come up with a model which combined a binary star system with the accretion disk idea. In Katz's "exploding accretion disk" model, SS-433 is a binary star in which one member is either a black hole or a neutron star — "It works with either," he says. The other star is perhaps an F-type star. The superdense companion is surrounded by an accretion disk, fed by matter spiraling in from the companion. But matter is coming into the disk so fast, says Katz, that the disk is overloading and radiation pressure lifts matter off the disk and blows it out in two jets perpendicular to the accretion disk, in the so-called "preferred direction."

The two jets are basically neutral hydrogen atoms and Katz says they are "as fragile as eggshells. It's sort of like shooting eggshells out of a gun. But if you want to do it without breaking them, it has to be at a slow speed.

"Hydrogen atoms are, in a sense, even more fragile than that, and to keep them from ionizing, they have to be accelerated at low temperatures and high density, and only the pressure of radiation will do that."

The gravitation of the companion star causes the 164-day period. The accretion disk is at an angle to the orbital plane, and so the twin beams boiling off the accretion disk (which is fed by the companion star) precess or "wobble" at that period.

Katz predicted a second period would also be found in SS-433's behavior, one of around five days, due to the orbital period. A second periodicity has in fact been found by David Crampton of the Dominion Astrophysical Observatory in Victoria, B.C. But the period is about



In the exploding disk model for SS-433, an excess of matter spiraling from an F-type star into the accretion disk of its superdense companion is blown off the disk by radiation pressure. This results in two jets of neutral hydrogen atoms perpendicular to the disk which precess or "wobble" with a period of 164 days because of the gravitation of the primary star. Artwork by Mark Paternostro.

thirteen days, not five. Katz, though, says he can live with that.

He also thinks his binary model ties SS-433 in with another stellar phenomenon, the X-ray star. SS-433's X-ray emissions, of course, are what started the whole round of bizarre findings about it. As an X-ray source, it has a luminosity of about 10^{35} ergs per second. But the total kinetic energy kicked out by the beams, on the order of 10^{40} ergs, is a hundred times that of the Crab Nebula. Since it can't do that for very long without running out of energy, it's probably a fairly young X-ray star. Certainly no others like it have been found.

The kinematic model and the exploding accretion disk explanation of the central object are not the only theories around, of course. George Collins II, Gerald Newsom, and Robert Boyd of Ohio State University have proposed their own theory for SS-433 which they think explains its behavior. One way in which their model differs from others is that it's *big*. "Ours is very large," says Collins, "occupying a volume of space somewhat larger than 20 times the size of our solar system — about 1,000 astronomical units in radius. The central binary of the system is only about one AU across."

In the Collins-Newsom-Boyd model, a hot blue star of about 50 solar masses is in orbit with a neutron star. The large blue star has an extremely strong magnetic field and a powerful stellar wind. The field tends to channel the ionized stellar wind material into two tight beams coming out of the poles. But the twin beams are frozen into the field and slung around as the magnetic field axis precesses under the influence of the neutron star. About a thousand astronomical units out, where the blue star's magnetic field strength drops to about one gauss, is where Collins says the action is taking place. Out there is a "trapped plasma, trapped in the magnetic field, going around in a carousel fashion, providing the emitted radiation" as the beams interact with it. He adds that he and his colleagues have not quantitatively evaluated everything, but he still believes this model accounts for "the X-ray observations, the radio observations, the infrared observations, and possibly the appearance of the supernova remnant."

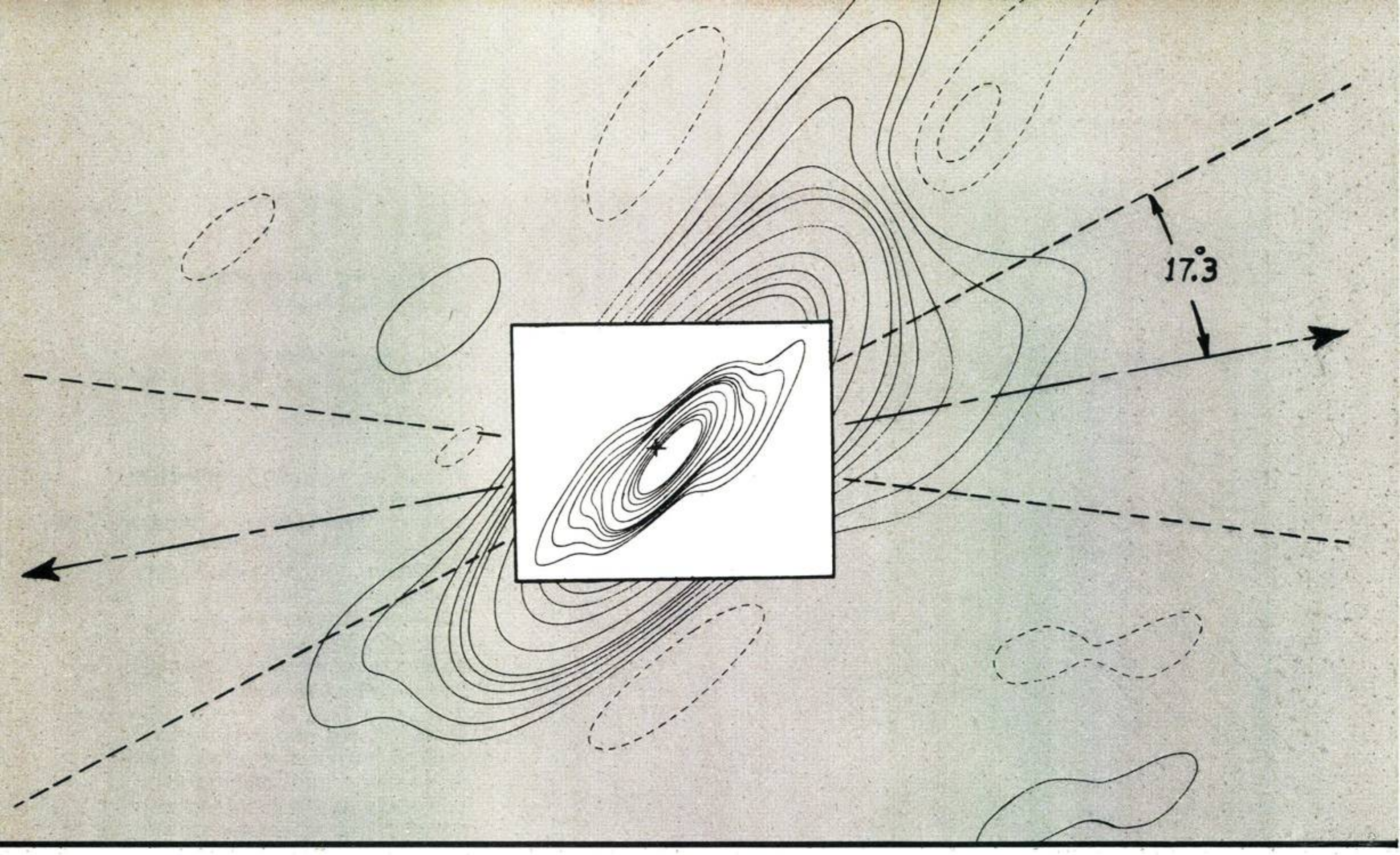
Since first publishing their model's description in *Nature* magazine in 1979, Collins and his colleagues have made additional observations of SS-433. In early March 1980 he reported finding a *third* periodicity in its behavior — a period of 6.55 days. Collins notes this is one-half the 13-day period found by David Crampton. That 13-day period is in the stationary lines of SS-443, and most people accept it as evidence of a 13-day period for the binary system model of SS-433.

The 6.55-day period, though, was found in the moving emission lines, superimposed on the 164-day period. "This implies the necessity of SS-433 being a very large system as we've described," said Collins. "We take it as strong confirmatory evidence." He thinks the other two periods found for SS-433 are "not significant for the system."

Collins feels his model explains another facet of SS-433, namely its location in what seems to be a SNR (supernova remnant), W50. He admits, though, that he's not even sure W50 *is* an SNR. "If it is, it's a filled supernova remnant, like the Crab. These are extremely unusual SNRs, and they all have some ongoing power source — the pulsar in the Crab, and SS-433 in W50.

"And it doesn't even have to be a supernova remnant," he adds. W50 could simply be the matter blown out of SS-433 by its twin beams, over the eons filling the interstellar space around it.

One person looking closely at the SS-433-supernova connection is Sidney *van den Bergh, director of the* Dominion Astrophysical Observatory at Victoria, B.C. "There are arguments on both sides," he says. On the "pro-supernova remnant" side, van den Bergh notes that the



The radio brightness of the SS-433 region is shown above at wavelengths of both 6 centimeters (inset) and 20 centimeters. Both maps were made with the Very Large Array (VLA) radio telescope near Socorro, New Mexico. The general elongation in each map is an instrumental feature caused by the distribution of antennas in the VLA. The significant features are the "spurs" projecting outward from the unresolved core, approximately in the direction of the bulges in the "supernova remnant" W50, indicated by the arrows. If this direction does in fact represent the axis of precession of SS-433's beams, then the dashed lines indicate the extreme positions of these beams during the 164-day period. Map courtesy of Ernest Seaquist and William Gilmore, David Dunlap Observatory, University of Toronto.

sulfur II lines in the object's spectrum are very strong in relation to the hydrogen lines. "This is common in supernova remnants, and we see it showing up here, too." On the other hand, the strength of the nitrogen lines in the spectrum is also very high, and that should not be the case with a supernova remnant. "Material ejected by a supernova is diluted by the interstellar hydrogen; it's hard to see how the nitrogen can be so high" if it is a supernova remnant.

The theories and models of SS-433 keep on coming. So do the observations — and the puzzles:

Jim Kemp of the University of Oregon has found that the total visible output of SS-433 can change by as much as half a magnitude in two days. And SS-433 seems to get redder as it gets brighter. Why?

An examination of old photographic plates from the Harvard Observatory shows SS-433 had its 161-164 day period as far back as 1929, but there's no evidence for it before then. Did SS-433 just "turn on" 51 years ago? How?

R.E. Spencer of the Jodrell Bank radio telescope in England has found that SS-433, as a radio object, consists of a compact core and a jet about one second of arc long. The jet is aligned at the same angle as a similar structure in the supernova remnant W50. Is this evidence of a physical connection between SS-433 and W50?

Mitchell Begelman of the University of California, and others, think SS-433 may be a binary consisting of a neutron star and a white dwarf in close orbit, with an orbital period of four to eight minutes. Relativistic effects warp space-time near the object, and the effect called *geodetic precession* is occurring: the orbital plane only appears to precess.

W. Kundt, in West Germany, suggests that SS-433 is a binary neutron star, one rapidly spinning with an accretion disk. This rapidly spinning member of the pair is only 10,000 years old, and the supernova remnant W50 may be associated with it.

Geoffrey Burbidge, director of the Kitt Peak National Observatory in Arizona, and David De Young of the National Radio Astronomy Observatory in Virginia, propose that SS-433 is a binary with *no* neutron stars or black holes involved. Rather, the system is a binary with a massive early-type star and a magnetic white dwarf. "A binary model is by far the most plausible," thinks Burbidge. "I'm very skeptical about disks around black holes."

Burbidge adds that he and De Young were spurred on to create their model by some of the speculations of others. "Here was this object and people were making extremely exotic models of it," Burbidge recalls. "Dave De Young and I sat down one afternoon and I said, 'Dave, I think we can do at least as well as that!' "

SS-433 has been observed now for almost two years, since that August night in 1978 when Bruce Margon first spotted its bizarre behavior. It remains a unique object, its actions not totally explained to everyone's satisfaction. What is not unusual has been the behavior of the astronomers and astrophysicists intrigued by it.

Says Geoffrey Burbidge: "It's the usual thing that happens whenever anything comes along that's rather exotic. The observational people come up with a strange phenomenon and then a series of theoreticians speculate about it at different lengths and at different depths."

No one's tiring of the game yet.

Joel Davis is a science writer living in Seattle. His most recent article in ASTRONOMY was "Asteroids: The Flying Mountains" which appeared in the May 1980 issue.

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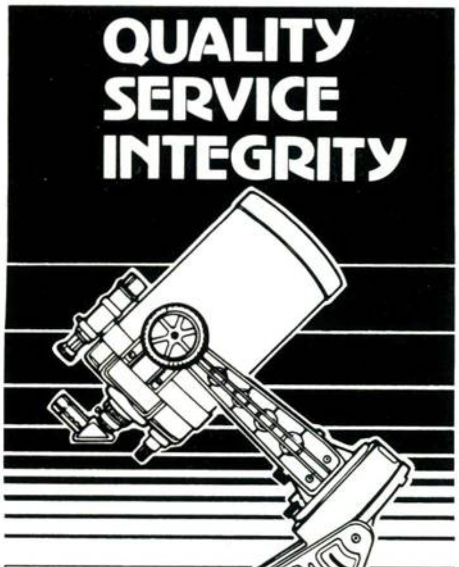

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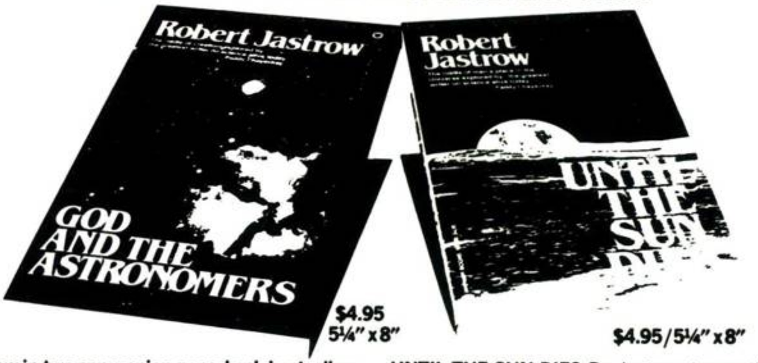

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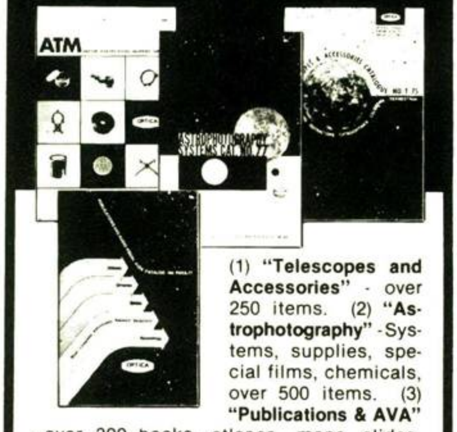

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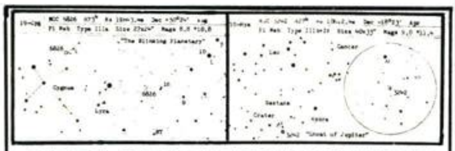

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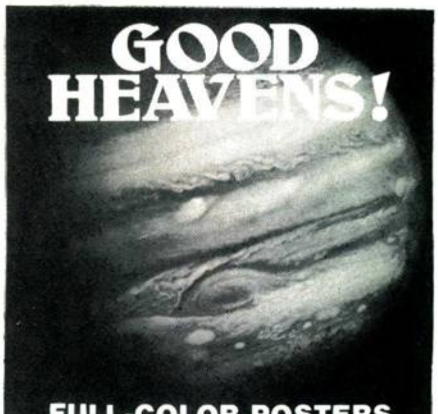

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close-up on hercules

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There's good stuff comin' along this month with the start of a Mercury elongation and a splendid view of Venus in the morning skies. Then the evening of the 15th is graced with a very pretty occultation of Jupiter. And last, a farewell to some departing friends: July is your final chance to have a full month of viewing Jupiter and Saturn until this fall.

Mercury

By the end of June, Mercury had vanished from view in the western sky after sunset. This month, on the 11th, it passes 4¾° south of the Sun's center, marking inferior conjunction.

Mercury's orbital motion is always rapid; even though it's currently near aphelion (and therefore moving about its slowest), you should begin hunting for it in the morning sky about 10 days after inferior conjunction.

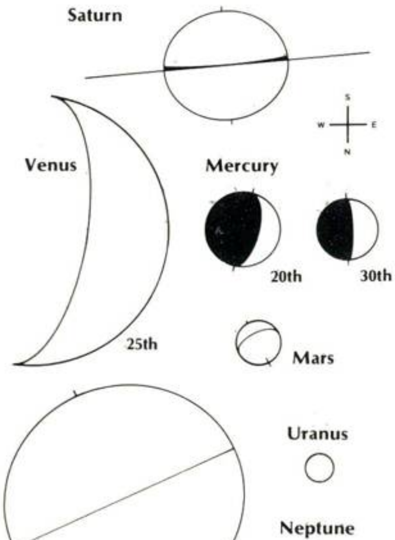
You'll be crowding the time of sunrise and looking for Mercury in steadily brightening skies — this apparition won't be more than a medium-good one. Greatest elongation comes on August 1st (in UT; July 31st in North American time zones), but maximum elevation comes a day or two later, See the diagram on page 84 which shows its path from late in July through mid-August.

Venus

Rising swiftly day by day into the morning sky, Venus presents a dazzling spectacle to early risers. Seen against the background stars of Gemini (until the sky lightens enough to fade them from view), the blaze of light from Venus will inevitably startle some people into thinking they're seeing a UFO.

Canadian Craig McCaw's shot of the famed Whirlpool Nebula (M-51) in Ursa Major takes first place in this month's "Best Astro-Photo" competition. Using a 16" telescope on Mount Kobau in British Columbia, the Vancouverite exposed Ektachrome 400 in a cold camera for 25 minutes at f/7.6.

Each time the planet passes through inferior conjunction and appears suddenly in the morning sky, it surprises many people (and probably alarms a few, too) as they head off early for work. On the 22nd comes maximum brightness — magnitude -4.2 — when its crescent phase will be 27% lit.



At this time it'll be just over 0.45 astronomical unit away (67 million kilometers) and will have an angular diameter of 37.3 seconds of arc.

Moon

Both Venus and Jupiter will be occulted by the Moon in July: Venus on the 9th and Jupiter on the 16th. Of the two events, the better by far is the one of Jupiter, coming as it does in the evening.

Jupiter's occultation will be visible from places west of about the 90° meridian of longitude. East of there, the Moon will have set by the time it covers the planet. The northern limit (where the Moon grazes Jupiter) runs northwestward along the Ontario-Minnesota border and then slices across the southern parts of Manitoba and Saskatchewan up into the middle of Alberta.

At most sites, disappearance comes between about 03:15 UT and 03:45 UT (the farther west your site, the earlier it happens); reappearance, 45 minutes to an hour later. Jupiter will be a little over 32" of arc in (equatorial) diameter, and the Moon will be a 15%-lit crescent, 4 days old.

(Remember that for this event, when you convert from UT into daylight time for your zone in North America, the time will come out on the previous day: You'll see the occultation on the evening of the 15th.)

The occultation of Venus on the 9th is an afternoon event (19:00 to 19:50 UT), and is visible south of a line running from about the 40° parallel of latitude on the east coast to the 45° parallel on the west coast.

Mars

Looking very small in your eyepiece, Mars doesn't offer a lot for telescopic observers. Its angular diameter is only 6.2" of arc on the 1st of July; this shrinks to 5.5" by month's end.

Yet as if to rub it in, we'll be seeing an ever-dwindling Mars in the evening sky for many months. Mars' close match to Earth's orbital speed (5½ km/sec) difference) will suffice to keep the Red Planet out of the Sun's clutches until early next year.

Asteroids

At magnitude 8.3, 1 Ceres is in eastern Taurus at $5^h 19.5^m$, +21° 34.0' (1950 coordinates) on the 15th of July. As this region rises about 4 a.m. local daylight time (LDT), you'll have to

universal time

Astronomers the world over use an unambiguous system of time reckoning based on a 24 hour clock, called Universal Time (UT). Times in Through the Eyepiece are UT unless noted otherwise. To convert UT into your local daylight time, subtract the following number of hours for each time zone: EDT, 4; CDT, 5; MDT, 6; PDT, 7; Alaska and Hawaii, 9. For example, if an event is to happen at 03:00 hours UT on June 7, then the time in EDT would be 11 p.m. June 6. Likewise, 03:00 UT on Sept. 2 becomes, in PDT, 8 p.m. on Sept. 1.

work quickly if you want to see the asteroid before twilight becomes too bright.

2 Pallas (magnitude 9.0) lies at 2ʰ 03.5ᵐ, +1° 07.6′ (1950) on the 15th, which places it in Cetus' tail. Since it rises around 2 a.m. LDT, you shouldn't find it too hard to locate.

Look in western Leo (at 9ʰ 58.9ᵐ, +10° 38.6′, 1950 coordinates) July 15th for 3 Juno, but the magnitude 10.4 object will be hard to find in the evening twilight. This part of the sky sets around 10 p.m. LDT.

4 Vesta, magnitude 8.3, lies in Gemini at 6ʰ 53.5ᵐ, +22° 25.1′ (1950) on the 15th. Because it was in conjunction with the Sun on the 25th of June, this minor planet will be very difficult to locate in the morning sky.

Jupiter

During July the Sun traverses Gemini and half of Cancer. Leo is next along the ecliptic and so your opportunities for viewing Jupiter are coming to an end — at least until it re-emerges from the solar blaze in late September.

Setting about 2 hours after the Sun, the giant planet in the south-central portion of Leo is low in the west as twilight ends. Telescopists searching out details in the swirling cloud belts will have to begin early — before the sky is fully dark — and carry on until the thickening atmosphere wipes everything out in a haze of bad seeing.

But observing in twilight isn't always

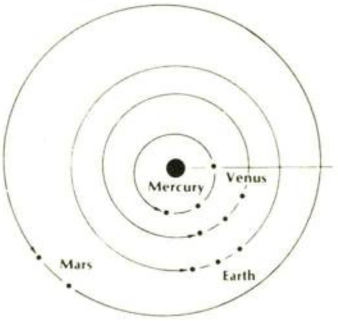
Planet Finder

Moon Data:

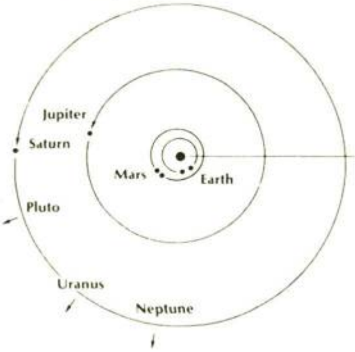
Last quarter	July 5 at 7:27
New moon	July 12 at 6:46
First quarter	July 20 at 5:51
Full moon	July 27 at 18:54
Last quarter	August 3 at 12:00
Perigee: July 4 at 16h	369,615 km
Apogee: July 19 at 0h	404,352 km
Perigee: July 30 at 23h	365,836 km

Planet	Date	R.A. (1980.6)	Dec.	Mag.	Distance (AU) from Earth	Distance (AU) from Sun
Mercury	10	7ʰ26.7ᵐ	17°14.8′	+3.0	0.57	0.45
	20	7ʰ05.2ᵐ	18°03.0′	+2.0	0.64	0.41
	30	7ʰ15.9ᵐ	19°53.8′	+0.6	0.83	0.36
Venus	10	5ʰ02.3ᵐ	17°53.8′	-4.1	0.37	0.73
	30	5ʰ37.1ᵐ	18°33.9′	-4.2	0.51	0.73
Mars	15	12ʰ09.3ᵐ	-0°40.1′	+1.2	1.61	1.58
Jupiter	15	10ʰ41.8ᵐ	9°23.9′	-1.4	6.08	5.42
Saturn	15	11ʰ35.9ᵐ	4°56.1′	+1.4	9.95	9.48
Uranus	15	15ʰ17.0ᵐ	-17°54.4′	6.0	18.25	18.76
Neptune	15	17ʰ18.9ᵐ	-21°42.1′	7.7	29.41	30.27
Pluto	15	13ʰ34.7ᵐ	8°32.3′	14.0	30.20	30.13

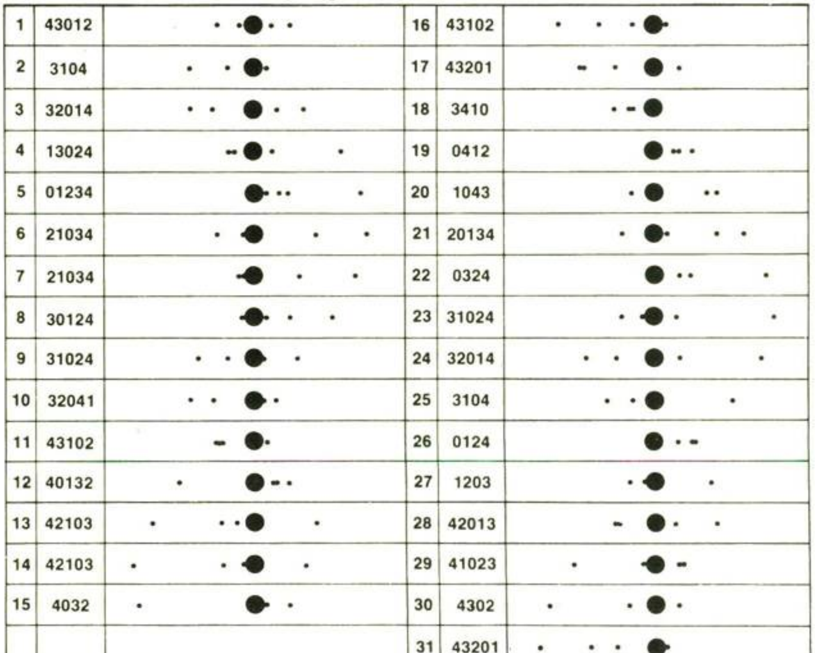
Inner Solar System



Outer Solar System



satellites of jupiter 02:00 ut



1	43012	16	43102
2	3104	17	43201
3	32014	18	3410
4	13024	19	0412
5	01234	20	1043
6	21034	21	20134
7	21034	22	0324
8	30124	23	31024
9	31024	24	32014
10	32041	25	3104
11	43102	26	0124
12	40132	27	1203
13	42103	28	42013
14	42103	29	41023
15	4032	30	4302
		31	43201

Jupiter = 0, Io = 1, Europa = 2, Ganymede = 3, Callisto = 4
(South is at top, matching the view in a telescope.)

The Sun rising behind the 120-inch telescope's dome at Lick Observatory was caught by the camera of Rick Baldridge (see observers' reports below). He used a 6" refractor as camera lens and 200 ASA film. The large bump in the center is the 120-incher's dome; near the right edge is the smaller 12-incher's dome.

regrettable. In fact, some people prefer it since looking at Jupiter in full darkness can seem like staring into a lit light bulb.

Around the 20th of July, Jupiter will pass about 2° south of two galaxies listed in the Messier catalog, M-95 and M-96. Try scanning with your low-power eyepiece from the -1.4 magnitude planet to the 9th magnitude galaxies. Your line of sight thus jumps from a distance of about 6 astronomical units to 25 million light-years!

(If you live in the western half of North America, don't forget the July 15th occultation; see the "Moon" section for details.)

Saturn

Being at the Leo-Virgo border, Saturn is in much the same position as Jupiter with regard to observing: You don't have a lot longer to see it. Saturn now sets about 3 hours after the Sun, and it, too, will disappear from view into the oncoming light of the Sun next month.

Saturn shines rather dimly (+1.4 magnitude), but as there isn't any star that bright at its location, 10° south and west of Denebola, you won't have trouble identifying it by eye; a glimpse through your scope will confirm it.

On July 23rd, the Earth slips through the saturnian ring-plane for the third and last time. Henceforth until the next ring passage in 1994, we'll be looking onto the northern side of the rings.

The Sun has been shining on the northern side since early March. When we cross through, it'll be a little more than 2° "above" the rings; as a result, the reappearance of the rings after the 23rd will be sudden. Watch for it.

Uranus

By the end of twilight in July, Uranus has passed the meridian, but hasn't set enough to make it hard to find. You'll locate it easiest if you start at Gamma (γ) Librae with a low-power eyepiece, then sweep south and west two degrees to an open triangle of three 6th magnitude stars: Zeta (ζ), 34, and 32 Librae. Uranus lies another 2° west (mostly) and south (a bit). Its diameter is 3.8" of arc; its brightness, 5.8 magnitude.

Neptune

To find Neptune, first locate Theta (θ) Ophiuchi in a low-power eyepiece and then scan 4° due north; Neptune will pass through your field of view. Its diameter is about 2.5" of arc and its magnitude 7.7.

observers' reports

From Rick Baldridge of the Peninsula Astronomical Society: ...a few members of our club and I had a beautiful observing night on March 15. As you know this was just about the best time to view most of the Messier objects. We opened the 16½" reflector and 6" refractor of Foothill College Observatory and started with M-31, M-32, and M-100, then moved progressively eastward, missing only M-74 and M-30. A few times we stopped to observe the planets, and we saw them all except Pluto, which would have taken too much time to find. Around 2 p.m., noting that seeing conditions were superb, we turned the scopes to some close double stars. We easily split Nu and Mu Sco, which are one second doubles. As dawn neared, and we finished off the last few Messier numbers, Mercury rose in the southwest — completing our planet survey.

I had done a few calculations a few weeks before, so we knew that the Sun

The Moon's passage through the Hyades on April 17th of this year was photographed by John Asztalos. Theta^1 (θ^1) Tauri, which had just emerged from occultation, lies immediately below the southern cusp of the Moon. Asztalos exposed Kodachrome 64 for 1 minute with a 200 mm lens at f/3.5.

was going to rise directly behind Lick Observatory some 25 miles to the east. We turned off the clock drive and set up for eyepiece projection on the 16½". The Sun rose directly behind the dome of the 120" reflector and proceeded southward, not quite reaching the dome of the 36" refractor.

So in one beautiful night we saw 108 of the 110 Messier objects, all the planets but Pluto, many close southern doubles, and sunrise behind Lick. It just goes to show what you can do....

From Donna J. Hughes: I thought you might be interested in hearing how small a telescope was necessary to find Pluto in the last couple of weeks while it was passing by a bright star. On April 18, the Santa Barbara Astronomy Club held a star party on a nearby mountain. Using the map of Pluto's path that you published in your magazine, a member with a 10" telescope quickly located it. Seeing how easy it was, Paul Sventek and I — both variable star observers, so we'll admit we've got trained eyes — easily found it in his 6" and my 8". It was just barely visible in the 6", but several other people confirmed it.

From Chuck Coates: Over the years I have had some very fine views of NGC-2903, perhaps my favorite non-Messier galaxy. With the dark skies of the Everglades, this galaxy definitely appears oval with a little texturing seen at both ends of its shape. My 12" f/5 is excellent on objects of this type, but NGC-2903 is one of those "if I only had a few more inches I'd see the spiral structure" objects. I've never actually detected it, but I'm sure it wants to show me. By the way, anything you might have heard about the viewing conditions in South Florida is true, but I did have some good viewing this past winter.

From Joe Rudich: It finally cleared off on January 13th, and I took the opportunity to observe a truly beautiful winter sky. My delight was then magnified tenfold: at 7:30 p.m. I was about a block from home, walking, when I spotted the most spectacular meteor of my life. It passed northwest to southeast through Ursa Minor and Ursa Major for about five seconds. The head was blue-white and about -6 magnitude, with a long, bright orange tail which seemed to flash on and off. Although "the best of my life" spans a mere 15 years, meteors have always been my special interest, so you can imagine how I enjoyed this!

close-up on hercules

Hercules is well-placed for telescopic observation in midsummer, riding high in the sky nearly directly overhead on July evenings. This huge but dim constellation, ranking fifth in size, contains no star brighter than third magnitude. The distinctive **Keystone**, however, formed by the stars Eta (η), Zeta (ζ), Pi (π), and Epsilon (ϵ), is easily identifiable. Containing two of the finest globular clusters and an assortment of double stars, this summer constellation has much to offer the telescopic observer.

Kappa (κ) Herculis is an optical double star, which means that the two components are not physically associated with each other but only happen to lie close together along our line of sight. Both stars are yellow-orange in color, with the primary about three times as bright as the secondary. Separated by a healthy 28 seconds of arc, their position angle is 12°.

Marking the southwestern corner of the Keystone, the binary star **Zeta (ζ) Herculis** consists of 3.1 and 5.6

magnitude components separated by only 1.4". Zeta is one of the closest binaries, lying just 30 light-years away, and its orbital period is only 34 years. The separation is currently slowly increasing, and will reach a maximum of 1.6" in 1990. The true distance between the two components varies from about 8 to 16 AU.

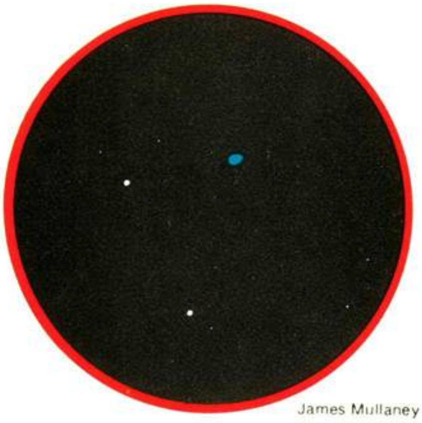
The famous **Hercules Cluster, M-13**, can be spotted with the naked eye (magnitude 5.7) about 1/3 of the way from Eta to Zeta in the Keystone. But a telescope is necessary to view this beautiful globular cluster in all its glory. M-13 is the best known of all globular clusters and the finest such cluster in the northern sky, being exceeded only by the extremely southern globulars Omega Centauri and 47 Tucanae. Perhaps the best description of M-13 is that given by the classic observer Barns: "In a small glass a curious olivine blur, often resolvable; but viewed with apertures of increased light-gathering power, a blazing panoply of suns of varied tints and staggering brilliancy." Even moderate-size instruments will resolve the brighter members of the cluster, revealed as a grainy texture overlying the pearly glow of tens of thousands more unresolved. The Great Cluster of Hercules lies about 25,000 light-years from us, and is in reality more than 150 light-years in diameter — a truly staggering conglomeration of blazing suns.

The planetary nebula **NGC-6210** offers a challenge to deep-sky observers. Lying slightly more than one degree southwest of fifth magnitude 51 Herculis, a line from Gamma (γ) to Beta (β) also points to its neighborhood. Sweeping with a low power, wide-field eyepiece will reveal a triangle of stars — one of which is actually the planetary. 20 by 13 seconds

M-13

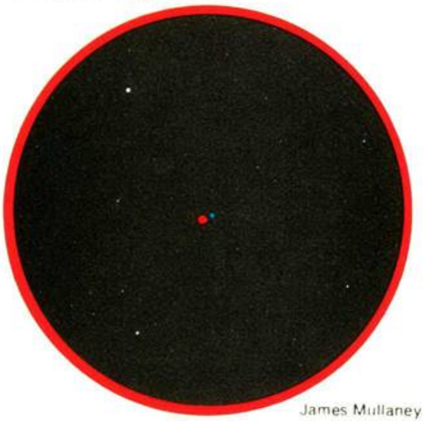
E. Ken Owen

NGC-6210



James Mullaney

Ras Algethi



James Mullaney

M-92

S. Faworski

of arc in size, NGC-6210 appears as a dim bluish-green egg.

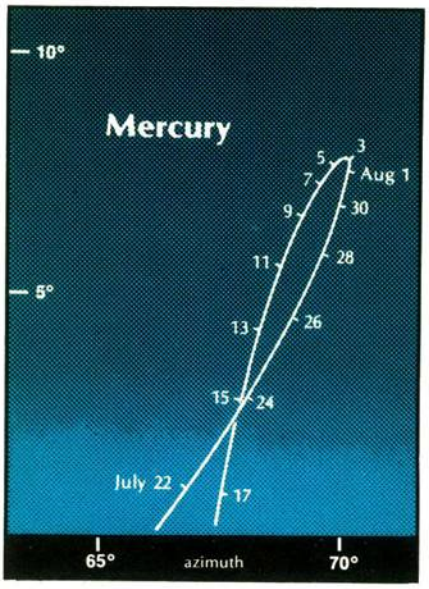
Situated midway between the two fifth magnitude stars 42 and 52 Herculis, the tiny globular cluster **NGC-6229** is much easier to find than NGC-6210. Long mistaken for a planetary nebula, this cluster appears as a fuzzy patch of light forming a triangle with two sixth magnitude stars.

Alpha (α) **Herculis** consists of a stunning combination of third magnitude orange and fifth magnitude blue-green stars separated by a comfortable 4.6 seconds of arc. Also called **Ras Algethi** (the kneeler's head), this double star has an especially strong color contrast, easy to see even for the neophyte guest observer at your eyepiece. The primary is an especially large red giant star, intrinsically many hundreds of times more luminous than our own Sun, but with an extremely low surface temperature. It is also variable, ranging from about third to fourth magnitude over a somewhat irregular period of 90 days. A good reference star to use in checking on Alpha's variability is **Delta** (δ) **Herculis**, 10 degrees due north and shining at a constant magnitude of 3.2. The two stars nearly match in brightness on some nights, while on others Alpha is noticeably fainter. The dimmer secondary has been found to be a spectroscopic binary with a period of 52 days.

Delta (δ) **Herculis**, like Kappa, is an optical double rather than a true binary system. It consists of a 3.2 magnitude primary attended by an 8.8 magnitude companion about 10 seconds away. Barns called this double "a study in color," and rightly so, for countless hues have been reported. Some observers see the pair as cream and lilac, but green and purple, pale yellow and bluish-green, green and ashy white, yellow-white and azure, and even greenish-white and grape red have been recorded. The actual spectral types of the stars are A3 and G4. What colors do you find for this "fake" but interesting double?

The eclipsing binary **68 Herculis** is also a visual double with a 10.2 magnitude companion located 4.5" distant at position angle 60°. The primary has a period of just over two days, and consists of two giant stars revolving rapidly about each other almost in contact. Primary and secondary minima occur at one-day intervals, alternating between magnitudes of 5.0 and 5.4, while the maxima are 4.6 magnitude.

Forming the top of a triangle with Pi (π) and Eta (η) Herculis, the top two stars in the Keystone, **M-92** is a bright, easy-to-locate globular cluster. Low power sweeping will readily pick it up despite the absence of any nearby guide stars. Often overshadowed by its more famous neighbor M-13, M-92 is a superb sight on its own. Why not compare the two on a transparent moonless night and see what you think of their respective appearance and relative merits?



Mercury's path in the morning sky 45 minutes before sunrise is shown here for an observer at 40° N latitude.

Rho (ρ) and **100 Herculis** are two doubles each consisting of pairs of hot, blue-white A-type stars. But there the similarity ends. The components of Rho differ by a magnitude in brightness, while 100 consists of two stars of nearly equal luminosity. 100 is a relatively easy pair separated by 14 seconds of arc (position angle 183°), while Rho is a much tighter double at 4" separation (position angle 317°). An interesting project is to compare the appearance of these two relatively nearby doubles in your telescope, scanning from one to the other.

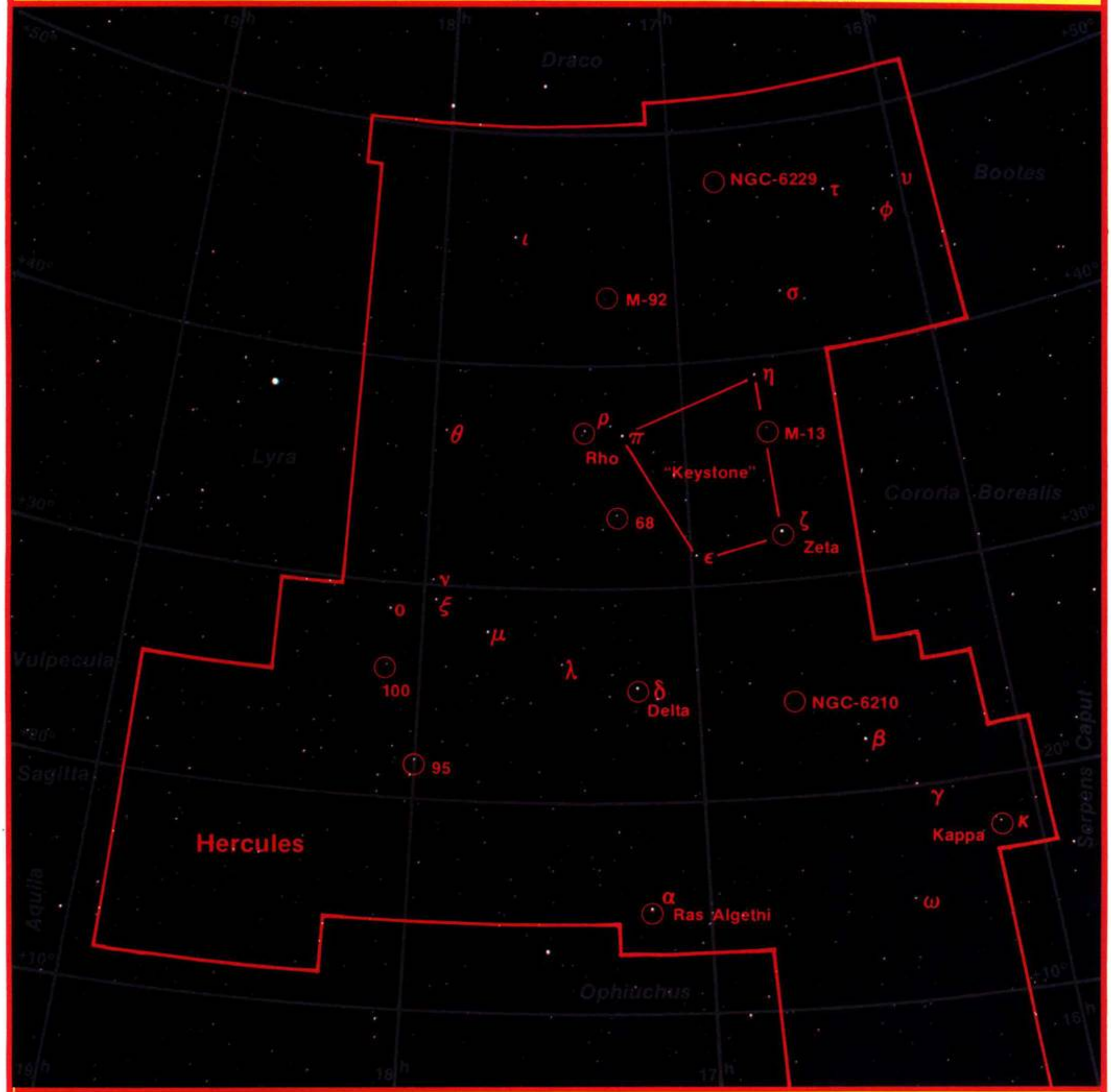
Found by extending a line from Epsilon (ε) to Lambda (λ) Herculis its own length again, the double **95 Herculis** offers one of the subtlest, yet most beautiful, combinations of celestial color in the sky. The components of 95 are 6.5 seconds apart and nearly identical in brightness, but with a fine color contrast. Most see this pair as pale green and pale red, though Barns poetically described the colors as "beryl and sardonyx." The tints are delicate but definite, and persistent in all apertures. How would you describe them?

One of the chief pleasures of amateur astronomy is comparing your own impressions at the eyepiece with those of others, both past and present. Or even better, why not join with a friend in observing the wonders of Hercules? As the old English proverb puts it, "A joy shared is a joy made double."

Map by Dewey Schwartzenburg

hercules

Photo by R. Provin & B. Wallis


Draco
Bootes
Lyra
Corona Borealis
Vulpecula
Sagitta
Aquila
Serpens Caput
Ophiuchus
19h
18h
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16h
+50°
+40°
+30°
+20°
+10°
NGC-6229
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NGC-6210
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95
γ
Kappa
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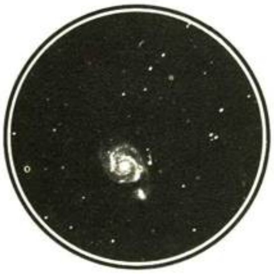
Hercules
α
Ras Algethi
ω

Object	Type	Mag.	Size/Sep. Per.	R.A. (1950)	Dec.	R.A. (1980)	Dec.
Kappa (κ)	★^{2}	5.3,6.5	28″	16^h06^m	+17°11′	16^h07^m	+17°06′
Zeta (ζ)	★^{2}	3.1,5.6	1.4″	16^h39^m	+31°42′	16^h41^m	+31°38′
M-13	●	5.7	20′	16^h40^m	+36°33′	16^h41^m	+36°30′
NGC-6210	■	9.7	20″x13″	16^h43^m	+23°53′	16^h44^m	+23°50′
NGC-6229	●	8.7	1.5′	16^h46^m	+47°37′	16^h46^m	+47°34′
Alpha (α)	★^{2},m★	3.0-4.0,5.4	5″,90^d	17^h12^m	+14°27′	17^h14^m	+14°25′
Delta (δ)	★^{2}	3.2,8.8	10″	17^h13^m	+24°54′	17^h14^m	+24°52′
68	Ӿ★,★^{2}	4.6-5.3,10.2	2.05^d,5″	17^h16^m	+33°09′	17^h17^m	+33°07′
M-92	●	6.1	8′	17^h16^m	+43°12′	17^h17^m	+43°10′
Rho (ρ)	★^{2}	4.5,5.5	4″	17^h22^m	+37°11′	17^h23^m	+37°10′
95	★^{2}	5.1,5.2	6″	17^h59^m	+21°36′	18^h01^m	+21°36′
100	★^{2}	5.9,6.0	14″	18^h06^m	+26°06′	18^h07^m	+26°06′

★	*Star*
★^{2}	*Double Star*
★^{3}	*Triple Star*
m★	*Regular Variable*
∩★	*Irregular Variable*
Ӿ★	*Eclipsing Variable*
○	*Open Cluster*
●	*Globular Cluster*
■	*Planetary Nebula*
□	*Bright Diffuse Nebula*
§0	*Elliptical Galaxy*
§S	*Spiral Galaxy*
§ʃ	*Barred Spiral Galaxy*
§#	*Peculiar/Irregular Galaxy*

SUMMER SKIES in the 80's . . .

WHIRLPOOL GALAXY, MESSIER 51. Many bright galaxies dot the summer skies and M-51, in Canes Venatici is perhaps the favorite among observers. Discovered by Messier in 1773, the spiral pattern of this famous galaxy may be seen in an eight inch telescope. This galaxy is now thought to be about 35 million light years distant with a mass of 100 billion suns, and a diameter approaching 100,000 light years.



NORTH AMERICA NEBULA. Also known as NGC 7000, large gas cloud was found in 1786 by Sir William Herschel about thirty degrees west of bright Deneb in Cygnus. On a very dark night, the amorphous glow of this distant object can be glimsed in a good binocular, though it is quite difficult in most telescopes. The Pelican Nebula IC-5067-0 to the immediate east is a photographic object, not visible to the eye.

THE SUMMER MILKY WAY. Perhaps for most of us, the most remarkable of all astronomical treasures is the sight of the bright Summer Milky Way. Stretching through Cygnus and down into Sagittarius, the stars become more dense as we peer toward the tightly packed center of our own spiral galaxy. Binoculars reveal clumpings and clusters; telescopes expose vast nebulae and vast numbers of stars seemingly incomprehensible.

MESSIER 13, THE HERCULES CLUSTER discovered by Halley in 1714. For northern hemisphere observers, this massive globular cluster is the most frequently observed. Located one-third the distance from Eta to Zeta, in the keystone of Hercules, this cluster lies 25,000 light years distant and consists of several hundred thousand stars across 170 light years. A 6-inch scope will begin to show many of the multitudes of stars within this cluster; in larger instruments the view is breathtaking.

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VISUAL OBSERVING:	WHIRLPOOL	NORTH AMERICA	MILKY WAY	MESSIER 13
Scope Requirements	6″ or larger	Binoculars or RFT	Naked eye or binocular	4″ or larger
Notable Features	Companion	Star Field	Star clouds	Dense stars
Magnification	80X	Very Low	Low as possible	100-200X
Eyepiece-type	Orthoscopic	Erfle or Plossl		Orthoscopic
Magnitude	8	1.3 total		6
PHOTOGRAPHY				
Optical needs	6″ or larger	135mm telephoto piggyback	50mm to 135 mm piggyback	8″ or larger
Color Film	Ekta-200	Ekta-400	Ekta-400	Ekta-400
B & W Film	103a0	103aE	103aE/Tri-X	103aE
f/ratio	f/4 - f/10	f/4 or faster	f/3 or faster	f/4 - f/10
Exposure Time: (color)	20 min.-1 hour	20 min.-1 hour	20 min.	30-45 min.
(B & W)	10-45 min.	30 minutes	30 minutes	10-30 min.

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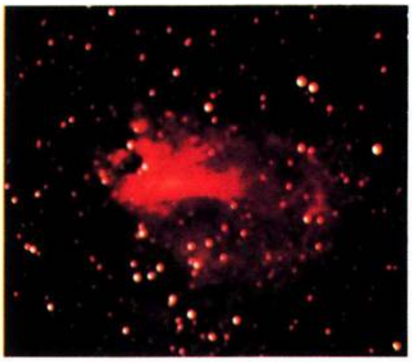
Rear view of the Dynamax 8 mounted on Dynamax Field Tripod

Front view of the Dynamax 8 mounted on field tripod



The Omega Nebula (M17) as photographed through the Dynamax 8.

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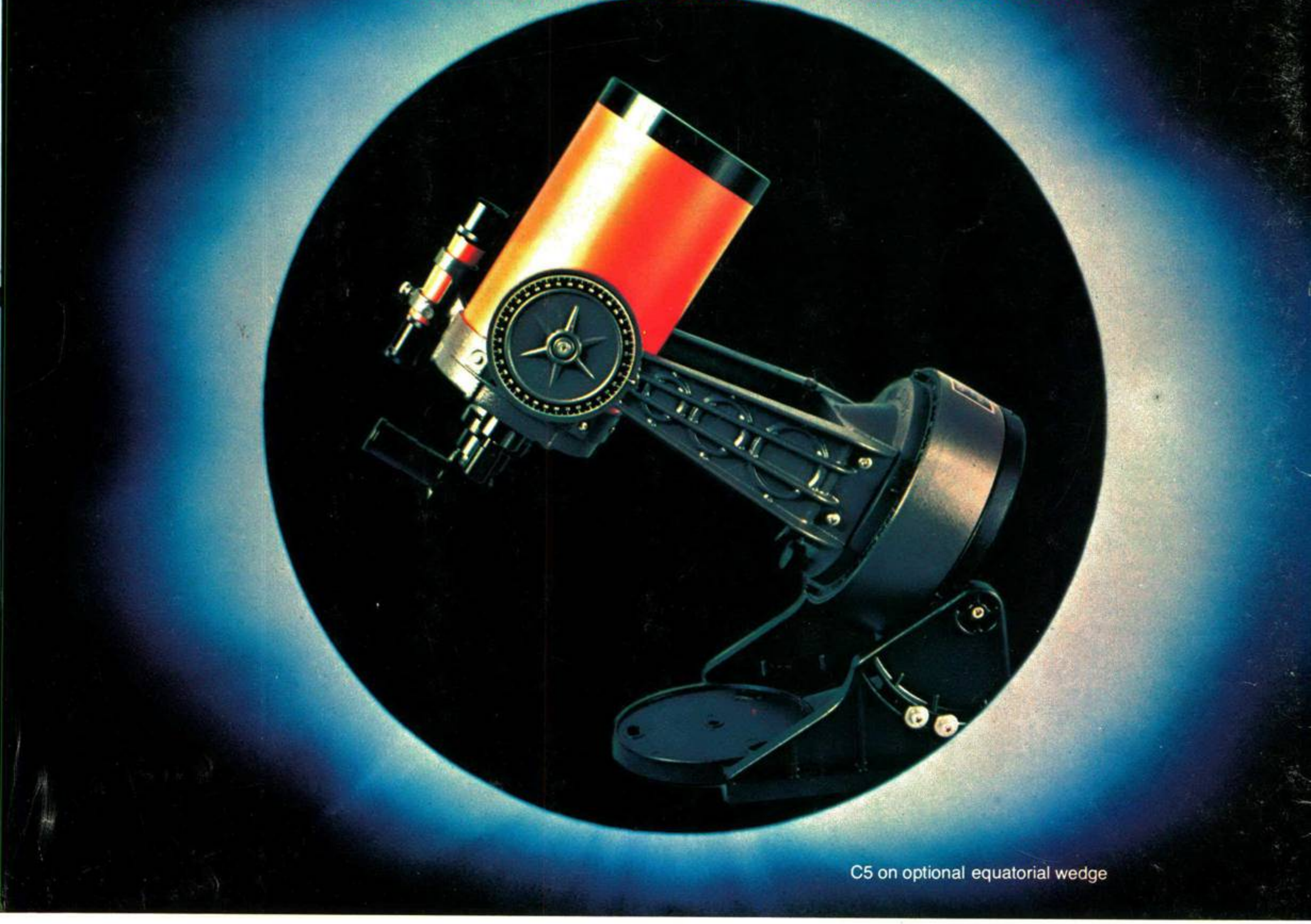
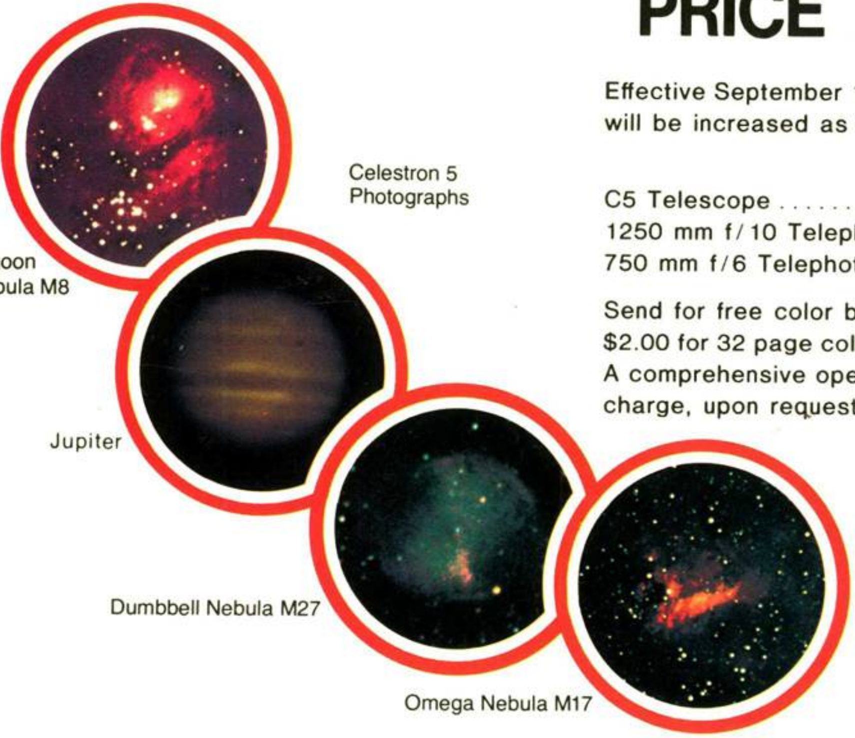


C5 on optional equatorial wedge



Celestron 5 Photographs

Lagoon Nebula M8

Jupiter

Dumbbell Nebula M27

Omega Nebula M17

PRICE ANNOUNCEMENT

Effective September 1, 1980 the base price of the Celestron 5 Models will be increased as follows:

	Current	After 9-1-80
C5 Telescope	$795.00	$925.00
1250 mm f/10 Telephoto	475.00	550.00
750 mm f/6 Telephoto	495.00	575.00

Send for free color brochure describing Celestron products, or send $2.00 for 32 page color catalog on how to select and use a Celestron. A comprehensive operating manual for the C5 will be sent for a $1.00 charge, upon request.

Celestron

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